CHAPTER-6

Autonomous Bodies

AUTONOMOUS BODIES

1.0 COUNCIL OF SCIENTIFIC & INDUSTRIAL RESEARCH

1.1 Biological Sciences

A chiral selectivity paralog of DTD for proofreading tRNA mischarging in Animalia

CSIR-CCMB identified emergence of totally new proofreading capabilities in the context of genome evolution and shown its implications for the evolution of Animalia. A new enzyme has been identified and characterized, which is present only in the context of Animalia, called Animalia-specific tRNA deacylase (ATD). While all the known proofreading during protein biosynthesis, apart from ribosomal proofreading, are associated with amino acid ambiguity, it has been shown for the first time that ATD corrects an error arisen from tRN Amis-selection. The proofreading activity of ATD is conserved across diverse classes of phylum Chordata. The study highlights the emergence of ATD during genome expansion as a key event associated with the evolution of Animalia.

DRB4 dsRBD1 drives dsRNA recognition in *Arabidopsis thaliana* tasi/siRNA pathway

The study by CSIR-CCMB highlights that the preferred orientation of tandem dsRNA binding domains in DRB4 allows the process of siRNA pathway initiation in plants. Further, domain selectivity and specificity leads to DRB4's multifarious activity in the post-transcriptional gene regulation mediated by tasiRNA & siRNA and antiviral response. The study exemplifies that the process of RNAi initiation is unique for each organism and is heavily dependent on multi protein assembly consisting of Dicer, its partner dsRNA binding protein and the trigger RNA. This work provides key mechanistic inputs for future design of gene silencing tools in plants.

The [Fe-S] biogenesis SUF pathway as a validated target in malaria parasites

CSIR-CDRI has provided the first experimental evidence for a functional SUF pathway for [Fe-S] biogenesis in the *Plasmodium falciparum* apicoplast (a relict plastid). Delineation of major steps and proteins of the pathway has since been completed and conditional knockout of sufS has demonstrated that the SUF machinery is essential for parasite growth in the mosquito vector. Essentiality of SufC in human blood stages of *P. falciparum* has been shown earlier. There are no known inhibitors of SUF proteins, necessitating a de novo approach to search for putative inhibitors for critical interactions such as those between desulfurase SufS and SufE, and scaffold components SufC and SufD. Molecular structure models for SUFs have been developed. It is being deployed in the drug discovery program at CSIR-CDRI.

Design of novel antimicrobial and anti-endotoxin peptides for the development of new anti-infectives

CSIR-CDRI has designed and developed a 15-residue novel peptide, S-016-1271, which is appreciably non-cytotoxic to human RBCs and murine 3T3 cells and possesses significant antimicrobial and anti-endotoxin activities. The peptide retains its antibacterial property in serum and physiological salts. The peptide is highly active against both Gram-positive and Gram-negative bacteria, fungi (*Candida albicans, Cryptococcus neoformans, Candida parapsilosis*) and Methicillin, gentamicin and multidrug resistant strains of *S. aureus*. Treatment of this peptide (single dose of 7 mg/kg) to mice administered with *P. aeruginosa* (ATCC BAA-427) showed 60% survival indicating appreciable efficacy

of this peptide in rescuing mice against this bacterial infection.

Artificial Small Intestine Helps Study Nutrient Absorption from food

CSIR-CFTRI and the Indian Institute of Food Processing Technology (IIFPT), Thanjavur, have developed an artificial small intestine system to test the level of absorption of micronutrients and other bioactive compounds from food. The artificial system consists ofa perfusion chamber fitted with ratintestine and requires just two hours to analyse the intestinal absorption. Methods currently in use are time consuming and not suitable for studying large number of compounds.

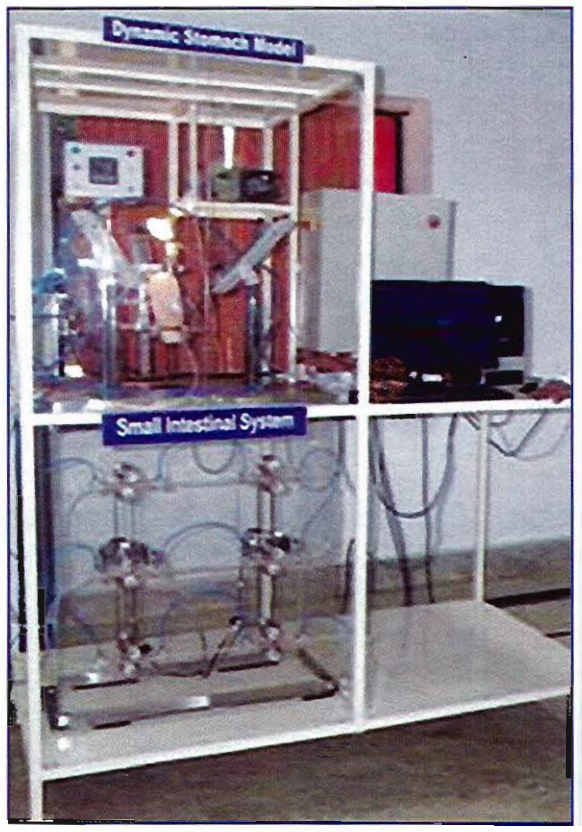

Fig. 1 Artificial small intestine system test setup

The artificial intestine system, simulates the exact physiological conditions and helps to evaluate both bio-accessibility and bioavailability of nano formulated bioactive compounds. The system has reduced the number of rats required for animal trials from 6-10 rats to just 2-3 thus taking care of the ethical issues that researchers face in carrying out *in vivo* studies. The researchers checked the permeability of both fat-soluble(vitamin E) and water-soluble (gallic acid) compounds using the new set up. While in the case of the fat-soluble compound, the permeability was higherin rats than the new system, the artificial system performed better for the water soluble compound.

A transcription factor from *Withania somnifera* regulates withanolide content and confers biotic stress tolerance through modulation of defense pathways

CSIR-CIMAP identified a transcription factor (*WsWRKY1*) from *W. somnifera which* regulates triterpenoids (phytosterols and withanolides) biosynthesis. Its knock-down causes stunted plant growth and reduced levels of triterpenoids while over-expression elevates the biosynthesis of triterpenoids. This factor interacts with W-box sequences that are present in the promoters of squalene synthase and squaleneepoxidase genes of sterol pathway for modulating their expression. Apart from enhancement of triterpenoids, this transcription factor also improves the tolerance to biotic stress in *W. somnifera*, highlighting its importance as a metabolic engineering tool for simultaneous improvement of triterpenoid biosynthesis and plant defense.

Terpene synthases of terpenoid and carbazole alkaloid biosynthesis pathways identified in curry tree (Murraya koenigii) through transcriptomic approach

Curry leaf (*Murraya koenigii L.*) is a rich source of aromatic terpenes and pharmacologically important carbazole alkaloids. CSIR-CIMAP carried out the transcriptome sequence of *M. koenigiileaf* and identified two terpene synthase genes (*MkTPS1* and *MkTPS2*) with highest in silicotranscript abundance. Their enzymatic characterization revealed that MkTPS1 produces primarily (-)-sabinene from geranyldiphosphate (GPP), while, MkTPS2 exhibits sesquiterpene synthase activity and produce (E,E)-α-farnesene from farnesyldiphosphate (FPP). Overall, the transcriptome data generated in this study will be a great resource and the start point for characterizing genes involved in the biosynthetic pathway of medicinally important carbazole alkaloids.

DNA barcoding for authentication and conservation of threatened species of genus *Decalepis* (Apocynaceae)

The endemic species of genus *Decalepis* are highly threatened by destructive wild harvesting. Medicinally important fleshy tuberous roots of *Decalepi shamiltonii* are traded as substitute to meet the international market demand of *Hemidesmus indicus*. The tuberous roots of all three species of *Decalepis* possess similar exudates and texture, and cannot be distinguished and authenticated based on conventional techniques. For accurate identification and authentication, CSIR-CIMAP developed DNA barcode reference library and a species-specific SNP position (230 bp) in the *matK* region, which is characteristic of *D. hamiltonii*, could be successfully used for specific assays enhancing its applicability for direct use in CITES enforcement for distinguishing it from *H. indicus*.

Plant Varieties developed and released

CSIR-CIMAP released the new varieties of *Ashwagandha* (Withania somnifera) and *Mucuna Pruriens*:

- CIM-Pushti (*Withania somnifera*): It is a With anolide A-rich, high-yielding advance breeding line of Ashwagandha (Withania somniferous) with commercially accepted root quality.
- CIM-Spurt (*Mucuna Pruriens*): This variety is developed through mutation breeding and has improved seed (21.5 ql/ha) and L-DOPA (98.90kg/ ha) yield

Development of Herbal Toothpaste

CSIR-CIMAP and CSIR-NBRI have developed jointly a 100% herbal toothpaste that could be a complete solution for oral problems. The CSIR herbal product, made by using six herbs and five essential oils, is chemical free and will help to fight problems like cavity, tooth sensitivity, bad odour and will also cure and tighten bleeding gums. Herbs such as majuphal known as gall oak and magic nut have been used. The herb is known for being very effective in curing bleeding disorders ranging from bleeding gums to excessive bleeding during the menstrual cycle. Other herbs like vajradanti and akarkara – known for the treatment of halitosis and tooth and gum problems have been used.

Establishment of herbal gardens in Ganga grams

The River Ganga is the fifth largest in world and third largest in Asia. Ganga basin, the largest river basin in India, has cultural, heritage and religious values. Four Ganga Grams: Bithoor Khurd, Bithoor Kalan, Katari Dodhi and KatariBidhara of Kanpur Nagar district, Uttar Pradesh which have historical, religious and tourist importance were selected by CSIR-CIMAP for in-situ/ex-situ conservation of medicinal and medicinally important aromatic plants under National Mission for Clean Ganga (NMCG). During 2017-18, government primary schools, scholar mission school and about one-acre land of Bithoor Nagar Panchayat was selected, and plantation of M&MIAPs viz. *Acoruscalamus*, *Andrographis paniculata*, *Aloe vera*, *Asparagus racemosus*, *Bacopa moneirii*, *Centella asiatica*, *Cassia senna*, *Phyllanthusniruri*, *Rauwolfia serpentina*, *Stevia rebaudiana*, *Withania somnifera*, etc. were done on large scale by CSIR-CIMAP.

Dissemination of Vetiver (*Chrysopogon zizanioides*) agro-technology

National Mission for Clean Ganga (NMCG) project (Ministry of Ayush) was initiated by CSIR-CIMAP with the aim to save the Ganga river basin from soil erosion, clean Ganga water, decontaminate the river basin soil, enhance the greenery and doubling the income as well as to improve the livelihood of the farmers living in these areas. In this ongoing project, agro-technology for flood prone areas were developed and about 5.0 lakh vetiver slips were transplanted in Ganga river banks of Varanasi, Mirzapur and Kanpur.

Fig. 2 Plantation of Vetiver slips at Ganga River banks in Varanasi

The awareness-cum-training programme related to decontamination, control soil runoff and enhancing income in flood prone/low productive lands located near Ganga were organized by CSIR-CIMAP.

eSkIN for Cosmetic Testing

CSIR-IGIB in collaboration with Pune-based firm Persistent System, has developed a software "eSkIN", a first-of its-kind computational platform for skin research that can ascertain the efficacy and adverse effects of cosmetic formulations. The computational platform could be a boon for cosmetic and pharma firms. Testing in animals to ascertain the efficacy and adverse effects of so far formed an integral and significant part of the process of discovery of new pharmaceutical and cosmetic products. The skin data analysis tool eSkIN, however, is a software with a collection of the large data available in the open domain offering an intuitive solution. Without torturing any animal and with just a few clicks, it will tell what will be the likely result of that data. eSkIN also converts large-scale high-throughput Omics data into biomedical knowledge. It is a repository of over 2600-plus skin-specific genes obtained by manual curation of biomedical literature.

Discovery of Skin Bacterium with Antimicrobial Activity

CSIR-IGIB has identified a new bacterial strain of *Staphylococcus capitals* which has a strong antibacterial activity against Gram-positive bacteria, including *Staphylococcus aureus*. CSIR-IGIB isolated the bacteria from the skin surface of a healthy human foot–specifically near the toes. Different bacteria are found in different niches of the skin. For instance, bacteria found in the arm pit are different from those found on the feet. The antimicrobial activity helps the bacteria to secure their niche environment by preventing other bacteria, including pathogenic bacteria, from colonizing. CSIR-IGIB also sequenced the genome of the bacteria and identified all the possible peptides that have antibacterial activity. And then, synthetic peptides with sequences identical to the natural ones isolated from the bacteria were synthesised. The synthetic peptides were found to possess antibacterial activity, opening the window to developing new antimicrobial compounds.

Heterologous expression of key carbon (C) and nitrogen (N) metabolic enzymes improves re-assimilation of photorespired CO_2 and NH_3, and growth

CSIR-IHBT investigated the effect of the heterologous expression of *phosphoenolpyruvate carboxylase (ZmPepcase), aspartate aminotransferase (GmAspAT), and glutamine synthetase (NtGS)* on carbon (C) and nitrogen (N) metabolism in Arabidopsis (Arabidopsis thaliana). These transgenes were expressed either separately or in different combinations. Heterologous expression of phosphoenolpyruvate carboxylase (ZmPepcase), aspartate aminotransferase (GmAspAT), and glutamine synthetase (NtGS) reduced the photorespiratory loss of C and N with concomitant enhancements in shoot biomass and seed yield in Arabidopsis (Arabidopsis thaliana). Upon feeding the leaf discs with glycine-1-14C, transgenic lines evolved significantly lower $14CO_2$ levels than the WT, suggesting a higher re-assimilation of CO_2 evolved during photorespiration. This work demonstrates that the heterologous coexpression of *ZmPepcase*, *GmAspAT*, and *NtGS* reduced the photorespiratory loss of C and N with concomitant enhancements in shoot biomass and seed yield.

Melatonin protects against lipid-induced mitochondrial dysfunction in hepatocytes and inhibits stellate cell activation during hepatic fibrosis in mice

Non-Alcoholic Fatty Liver Disease (NAFLD) affects millions worldwide and increasing for many reasons, most common being obesity. If unaddressed, it often developed to Non-Alcoholic Steato-Hepatitis (NASH), which causes inflammation of liver. There is no single medicine to cure. CSIR-IICB presented the pharmacological interventions for the disease by studying that lipid generates reactive oxygen species (ROS) in consequence to mitochondrial fission followed by inflammation in propagating hepatic fibrosis. The interaction of SIRT1/Mitofusin2 is critical for maintaining mitochondrial integrity and functioning, which is disrupted upon excess lipid infiltration during the progression of steato hepatitis. High glycolytic flux generates metabolically unfavorable milieu in hepatocytes leading to inflammation, which is abrogated by melatonin. Subsequently, melatonin

reduces hepatic fat deposition and inflammation in HFD-fed mice. Thus, melatonin disrupts the interaction between steatotic hepatocyte and stellate cells, leading to the activation of the latter to abrogate collagen deposition. Altogether, the results of the current study by CSIR-IICB have shown that excess lipid infiltration disrupts mitochondrial functioning that potentiates ROS production to initiate steato-hepatitis could be ameliorated by a potent anti-oxidant, Melatonin. It also prevents activating stellate cells and collagen formation, a crucial step to develop NASH. Thus, Melatonin alone or in combination with lipid-lowering drug will be useful to treat NASH.

Biodegradable Neuro-Compatible Peptide Hydrogel Promotes Neurite Outgrowth, Shows Significant Neuroprotection, and Delivers Anti-Alzheimer Drug:

Human brain is comprised of millions of neurons that interconnect and maintain its function. Due to the complexity of the brain, repairing the damage is a challenging task. Recently developed neuron transplantation-based approach often suffer from poor in vivo survival rates due to lack of biocompatible transplantable scaffold. To address this issue, CSIR-IICB has developed a novel peptide-based neuro-compatible hydrogel for transplantation of regenerated neurons into damaged area of brain. This work reveals that hydrogel is capable of auto release neuro protective molecules, maintain healthy neurons (2D and 3D neuron culture), encapsulate and release neuro-drug. Results of the study revealed that this hydrogel is non-cytotoxic, promotes neurite outgrowth, stabilizes microtubule networks, and enhances the expression of some key neural markers in rat cortical primary neurons. Further, this hydrogel exhibits significant potential in neuro-regeneration and also promotes fast recovery of the sham injured mice brain. Moreover, CSIR-IICB has found significant enhancement of reactive astrocytes in the hippocampal DG region of the sham injured brain, indicating its excellent potential in neural repair of the damaged brain. Finally, above results clearly indicate that this neuro-regenerative hydrogel is highly capable of maintaining the cholinergic balance through local release of acetylcholine in the injured brain, which is crucial for brain repair.

Inhibition of Twist1-mediated invasion by Chk2 promotes premature senescence in p53-defective cancer cells

In this study, CSIR-IIIM demonstrated that ectopic Checkpoint kinase 2 (Chk2), as well as its induction by natural podophyllotoxin analog, 4'-demethyl-deoxypodophyllotoxin glucoside (4DPG), efficiently blocks cancer cell invasion, scattering and thereby highlighting its potential role in cancer prevention. Detailed mechanistic studies reveal that Chk2 negatively regulates Twist1 promoter activity as well as interacts steadily with Snail1 protein to curb Epithelial-Mesenchymal Transition (EMT). Interestingly, increased Chk2 expression promotes premature senescence in the cancer cells evident from the distinctive increase in senescence-associated β-galactosidase (SA-β-gal) activity, G2/M cell cycle arrest and induction of senescence-specific marker $p21^{waf1/Cip1}$. Moreover, CSIR-IIIM also validated that 4DPG treatment significantly abrogates tumor growth as well as metastatic lung nodules formation in mouse mammary carcinoma model. Together these results validate the findings and unveil a novel strategy of Chk2-mediated Twist1 suppression that promotes premature senescence and prevents the metastatic dissemination of the p53-defective invasive cancer cells.

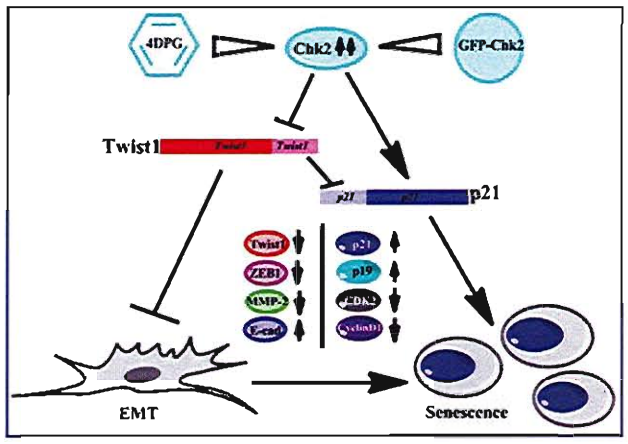

Fig. 3 Schematic representation of Epithelial-Mesenchymal Transition (EMT)

Discovery and Preclinical Development of IIIM-290, an Orally Active Potent Cyclin-dependent Kinase Inhibitor

Cancer is one of the deadliest disease of human mankind with high prevalence throughout the world.

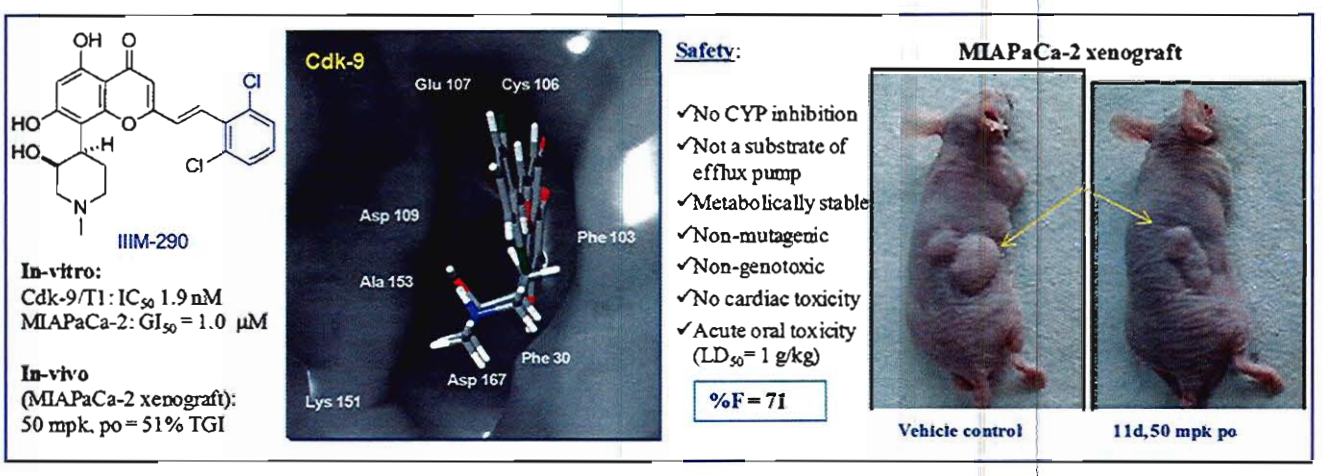

Fig. 4 Schematic representation of IIIM-290, an Orally Active Potent Cyclin-dependent Kinase Inhibitor

Particularly, for pancreatic cancer there is extreme scarcity of drugs. Thus, there is great need of newer and effective medicines for treating patients suffering from pancreatic cancer. CSIR-IIIM has been working in the area of natural product based drug discovery for cancer since last 6-7 years. From this oncology drug discovery program, the preclinical lead candidate IIIM-290 has been identified which has shown excellent efficacy and safety profile in cellular as well as in animal models of the cancer. This lead compound is a semi-synthetic derivative of the natural product "rohitukine", a major constituent of Indian medicinal plant Dysoxylum binectariferum. The drug candidate has excellent oral bioavailability. IIIM-290 potently inhibits the cyclin-dependent kinase-9 (with IC_{50} value of 1.9 nM), the enzyme which is responsible for proliferation of cancer cells. In cellular assay, it showed inhibition of the growth of pancreatic cancer cells with IC_{50} value of 1.0 µM and was found to be highly selective for cancer cells over normal fibroblast-cells. It showed excellent in-vivo efficacy in animal model (human xenograft model) of pancreatic cancer at 50 mg/kg dose, after oral administration. This lead compound does not show any liabilities of cytochrome 450 inhibition, or the substrate of efflux pumps and it does not cause cardiotoxicity, mutagenicity and any effect on male fertility in rats.

The preclinical studies as per Schedule Y of the Drugs and Cosmetics Act 1945 have been completed and IND application is being file to DCG(I) for seeking approval for conducting Phase I clinical trial.

New Drug lead for Triple Negative Breast Cancers

Globally, Breast cancer remains largest cause of cancer associated deaths in women. Scientists have now established that Breast cancer is not a single disease and isn't the same for every woman and even not at the cellular level. Clinically breast cancer is categorized in three major subtypes based on the expressions of hormone receptors, Luminal (ER^+, PR^+), HER2 enriched ($HER2^+$) and Basal/Triple Negative (TNBC). TNBC subtype is negative for ER/PR and HER2 expression, which represents the most aggressive and lethal among all subtypes of breast cancer. There is no target based drug for TNBC, and chemotherapy is the only available treatment option. CSIR-IIIM, Jammu initiated work on target specific kinases termed as Cyclin Dependent Kinases (CDKs) that are involved in cell growth and proliferation. The primary aim of their study was to focus on natural products scaffold isolated from marine species.

CSIR-IIIM reported the discovery of new chemical entity for the treatment of Triple negative breast cancer (TNBCs). By extensive medicinal chemistry and screening efforts a lead compound "IIIM368" was discovered, which have good physic-chemical properties (Solubility, stability, ligand efficiency), Pharmacokinetics, plasma exposure)

and promising activity in biochemical and cellular assays at nanomolar potency against CDKs. The lead compound (IIIM368) has also shown significant tumor growth inhibition (90% at 15mg/kg) in mice model of TNBCs without any mortality. IIIM368 has also shown excellent therapeutic index (selectivity, safety, activity) compared to natural product scaffolds.

Microbial F-type lectin domains with affinity for blood group antigens

CSIR-IMTECH has made a significant academic impact in the area of molecular glycobiology, particularly with respect to fucose-binding lectins. The Institute has biochemically characterized the glycan-binding specificity of F-type lectin domains from proteins of *Cyanobium sp.* PCC 7001, Myxococcushansupus and Leucothrix mucor. Although all three F-type lectin domains recognized the blood group H antigen motif on fucosylatedglycans, they differed in their fine oligosaccharide binding specificity. Cyanobiumsp. PCC 7001 F-type lectin domain exclusively bound to extended H type-2 motif, *Myxococcus hansupus* F-type lectin domain bound to B, H type-1 and Lewisb motifs, and *Leucothrix mucor* F-type lectin domain bound to a wide range of fucosylatedglycans, including A, B, H and Lewis antigens.

Arsenic Induces Hippocampal Neuronal Apoptosis and Cognitive Impairments via an Up-Regulated BMP2/Smad-Dependent Reduced BDNF/TrkB Signaling in Rats

Arsenic is a major environmental toxicant, affecting above 200 million people world-wide. Contaminated drinking-water is a key route of human exposure to arsenic, which results in various types of neuronal alteration. The hippocampus sustains memory functions, and hippocampal neuronal atrophy forms an important reason for cognitive impairments. In this study, CSIR-IITR hypothesized that arsenic induces hippocampal neuronal loss involving an interlinked BMP and BDNF mechanism of action through *in vivo* and *in vitro* studies. Arsenic enhances hippocampal neuronal cell death (apoptosis) and cognitive impairment involving increased BMP2-dependent attenuated BDNF/TrkB signaling. The study demonstrates that arsenic promotes hippocampal neuronal apoptosis through an up-regulated BMP2/Smad-dependent attenuation of BDNF/TrkB pathway, inducing cognitive deficits.

Lychee-associated acute hypoglycaemic encephalopathy outbreaks in Muzaffarpur, India

CSIR-IITR carried out study related to understanding the causation of acute encephalopathy syndrome (AES) and its correlation with Litchi consumption by children of Muzaffarpur, Bihar. CSIR-IITR studies on the causative factors of Litchi revealed the association of AES with Litchi consumption in under nourished or starved children. It was found that, the disease is due to the presence of MCPG in Litchi pulp. Awareness was created in the area in this regard and as a result, there has been no mortality due to AES since 2015 in Muzaffarpur, Bihar.

Discovery of new taxa as well as new national and regional geographic records of several plant and lichen taxa

CSIR-NBRI's study on Teloschistacean lichens led to the discovery of a new genus Upretia and a new species, *Gallowaye llaawasthiana*. CSIR-NBRI also recorded a globally threatened flowering plant species, Hoya pandurata, from India for the first time from Kamjong district of Manipur, bordering Myanmar.

Novel Way to Inhibit Bacterial Growth discovered

Antibiotic resistance is a problem that necessitates the identification of new antimicrobial molecules. CSIR-CCMB discovered a new mechanism to inhibit bacterial growth, paving the way for novel antibiotics to fight against infections resistant to drugs. An Antimicrobial Protein (AMP) was isolated from the milk of a unique egg-laying mammal, namely, Echidna, also known as spiny anteaters found in Australia and New Guinea. The extracted protein may serve as an alternative to antibiotics used on livestock. The Antimicrobial Protein (AMP) in the milk of the mammal can puncture the cell membranes of multiple bacterial species thereby destroying the infection. The study has been published in the journal *Biochimicaet Biophysica Acta–Biomembranes*.

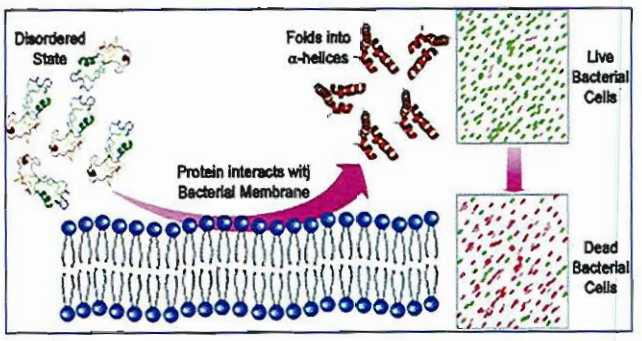

Fig. 5 Inhibiting Bacterial Growth

Fig. 6 Graphene-based Super capacitors from Lithium-ion Batteries

1.2 Chemical Sciences

Graphene-based Super capacitors from Lithium-ion Batteries

Millions of rechargeable Li-ion batteries are disposed each year due to its short life span of 2-4 years. The use of these batteries importable electronic devices and electronic vehicles would further contribute to the electronic waste problem. A new eco-friendly recycling process of these widely used Li-ion batteries has been developed by CSIR-CECRI and CSIR-CSMCRI. They have produced grapheme from discarded lithium-ion batteries which could potentially be an ideal material for next generation high-performance super capacitors. Grapheme oxide collected from Li-ion batteries showed high specific capacity at low current, 112 farads per gram which is almost equal to commercially ones. The process involves conversion of graphite into graphene oxide by oxidation and subsequent exfoliation which is then further converted into reduced graphene oxide. The new electrodes made using the reduced graphene oxide showed high stability and high retention capacity. When exposed to 20,000 cycles of charging and discharging at a high current density, electrodes retained 70% of their efficiency even after 85 cycles. The efficiency slowly increased and reached 108% after 20,000 cycles. The process is faster and cheaper than the ones available in market today for generating reduced graphene oxide at lower temperatures.

Synthesis of Quantum dots from 2D Materials

CSIR-CECRI has reported an oval single step electrochemical route for the synthesis of tungsten-di-

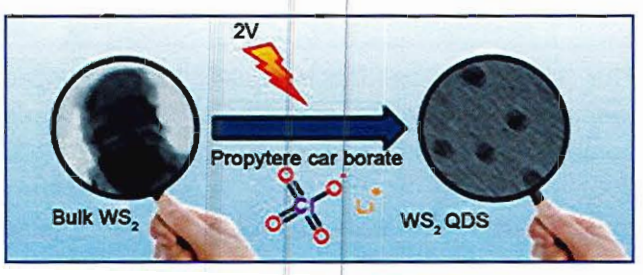

Fig. 7 Schematic representing the single step electrochemical transformation of bulk WS to WS quantum dots

sulfide quantum dots(WS_2)from their bulk counterpart. The average size of the WS2QDsis3nm±1nm(N=102) with few layers. This unprecedented electrochemical avenue offers a strategy to synthesize size tunable WS_2 nano-structures. Time dependent Transmission Electron Microscopy investigations revealed that time has played a vital role in this electrochemical transformation. This electro chemical transformation provides a facile method to obtain WS_2 QDs from their bulk counterpart which is expected to have greater impact on the design and development of nanostructures derived from 2D materials. Further, the QDs thus obtained exhibited higher photo-luminescence (PL) quantum efficiency (5%) and exhibit an excitation-wavelength dependent photoluminescence.

Integration of Silver Nanowires onto Boron-doped Graphene Nanosheets

A collaborative effort between CSIR-CECRI with MG University and UNSW Australia reported the integration of silver nanowires onto the boron-doped graphene nanosheets by a simple two-step process. In this work, the growth of AgNWs is supported by

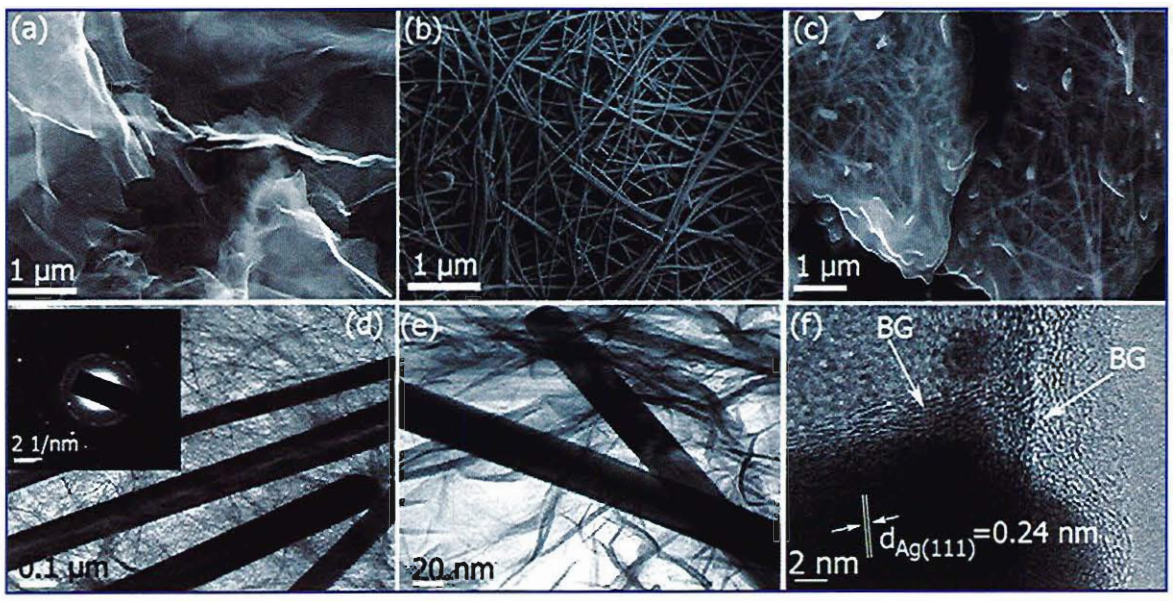

Fig. 8 FESEM images of (a) boron-doped graphene (BG); (b) Silver Nanowires (AgNWs); (c) BG wrapped AgNWs; (d, e) High resolution image of BG wrapped AgNWs; the inset shows selected area electron diffraction pattern of BG wrapped AgNWs; (f) High resolution transmission electron microscopic image of BG wrapped AgNWs

the choice of boron-doped graphene sheets as the template. The strong adsorption and the partial reduction of boron-doped graphene sheets towards metal ions in the solution provided the initial nucleation sites, moreover, it enhances the growth of long metal nanowires and therefore it facilitates the charge transfer. This one step process resulted in the formation of interconnected graphene-AgNWs networks without any interfacial problems.

This is the first report on the *in situ* reduction of AgNWs over boron-doped graphene sheets for ORR applications. Furthermore, according to authors, the BG wrapped AgNWs show excellent ORR activity, with very high onset potential and current density and followed four electron transfer mechanism with high methanol tolerance and stability towards ORR. The results are comparable to the commercially available 20% Pt/C in terms of performance.

Corrosion Resistant Inhibitive Admixture For Portland Pozzolana Cement

CSIR-CECRI has developed a process to get corrosion resistant inhibitive admixed Portland Pozzolana Cement Concrete. The process involves a simple step of adding inhibitors during manufacturing of cement or while making concrete at site. The added chemicals are in powder form and can be mixed at the factory itself, while producing cement or during making concrete. Due to corrosion resistant, this product can be used for constructions in aggressive marine environments. The technology has been transferred to Cleanflo India Pvt Ltd., Delhi.

New Device to Detect Cracks in Bridges

CSIR-CECRI has developed a portable device to monitor weak structures and send alerts whenever a crack is observed. The smart device alerts structural engineers about cracks on large structures and bridges well in time. The device called the Triboluminescence (TL) camera uses a light emitting compound and a smart camera that allow detection of cracks – invisible to the naked eye – on structures made of concrete, metal and fibre-reinforced plastic. This compound is coated on a surface which when rubbed, scratched, pulled or ripped emits light due to excessive pressure and the smart camera is programmed to capture it. The images can be shared through cloud storage or a mobile app, web browser or Bluetooth. The central portion and beams

of a bridge or a flyover, considered the weaker parts, can be coated with the compound. When vehicles move on the structure and these portions come under pressure, a red light is emitted wherever there are cracks. These cracks may otherwise not be visible to the naked eye. A record of these cracks can be kept through a smart camera that is programmed with an image sensor analysis software. The camera identifies the light emitted by the compound and captures an image. The images can be accessed with details like date and time and width of the crack. The technology could be a boon for the railways where there are several old bridges.

High grade gelatin and protein hydrolysate from trimmings waste of leather manufacturing industry

A Simple process technology has been developed by CSIR-CLRI to extract gelatin and protein hydrolysate from the trimmings waste with zero wastewater discharge incorporated in the system. Gelatin obtained is of high gel strength > 200 g and is suitable for making capsules. The developed technology not only addresses the issue of solid waste disposal; it also provides scope for high value realization from the trimming wastes. Great opportunity for substitution of gelatin import as annually India imports gelatin worth US$ 80 million (Rs 512 crores), mainly utilized for making capsules. The technology has been transferred to M/s. Anipro manufacturing Company, Chennai

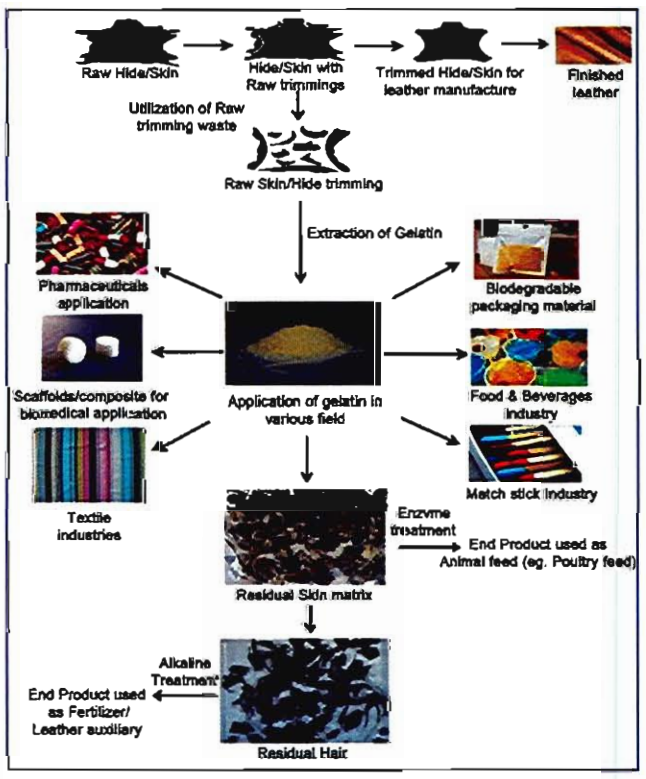

Fig. 9 Process for extraction of gelatin and protein hydrolysate for leather waste

Spent wash management technology

CSIR-CSMCRI, in collaboration with M/s Chem Process Systems Private Limited, have developed complete technology solution for valorization of spent wash generated in sugarcane molasses based alcohol distillery. The process allows utilization of spent wash for production of value-added by products, viz., potash fertilizer, animal feed ingredient etc., while achieving statutory compliance with 'zero liquid discharge' norms. Preliminary economic analysis for implementation of the technology in a 100 klpd distillery suggest a CAPEX payback period of about 3.5 years. The process know-how have been licensed to M/s Aurangabad Distillery Limited, in January 2018.

Recovery of sodium salts from tannery wastes

Separation of pure sodium chloride and sodium sulfate from solid waste of tanneries: Presently, in order to conform to 'zero liquid discharge' norms, the effluent released from tanneries is subjected to reverse osmosis (RO) for water recovery and the RO reject stream is evaporated to dryness. While the water recovered in course of evaporation is recycled, the solid residue (salt mixture) is stored. Increasing quantum of the stored salt mixture has created huge environmental problem and necessitated development and implementation of technology solution(s) for recovery of commercially acceptable material(s), thereby eliminating/minimizing the need for storage/disposal. CSIR-CSMCRI has developed a cost effective process to recover pure sodium sulfate and sodium chloride from the solid waste.

Development of Quast-Solid Polymer Electrolyte

A new class of quasi-solid polymer electrolyte matrix that supports appreciably fast single-ion conduction

has been synthesized by CSIR-IICT. The institute showcased as the first example of tailoring a lithiated anionic polymer employing semi-interpenetrating polymer networks approach, the study probes several key factors, such as, (i) polymer–polymer/ion–polymer interactions (ii) phase homogeneity, (iii) effect of oligomeric plasticization, (iv) transition temperatures and thermostability, and (v) H-bonding and degree of crystallinity for a series of binary and ternary compositions, and determines their effect on the overall electrochemical properties.

Development of Anti-TB Cocrystal 4-FDC Drug with Improved Stability

CSIR-NCL in collaboration with University of Hyderabad has developed an Anti-TB co crystal drug with improved stability. The pharmaceutical co crystals of INH (INH-Caffeic acid and INH Vanillic acid) were used to improve the stability of 4-drug FDC (4 drugs Fixed Dose Combination). The team showed that the pharmaceutically stable co crystal of INH is able to improve the stability greater than 5-fold compared to the current 4-FDC drugs. The conformer additives which stabilize the formulation are pharmaceutically accepted excipients. Stability studies were carried out under accelerated conditions of 40°C temperature and 75% relative humidity. The first time improvement of stability of anti-TB 4-FDC drugs using co crystals of INH in a fixed dose formulation was reported.

Efficient Delivery of Pesticide to Plants and Crops

CSIR-NCL has identified a natural material that can force water drops to stick to the surface of plant leaves. This natural material when mixed with a pesticide can address major environmental problems occurring due to contamination by pesticide wastage. Typically, pesticides are mixed into water and sprayed on plants and crops. But these sprays bounce off leaf surfaces due to the protective waxy layer that coats all leaves. So, to ensure that sufficient pesticide reaches the plants, an excess of it is sprayed accounting for these losses. Agricultural run-off due to pesticide overuse contaminates soil and groundwater, posing a significant environmental challenge. Some adjuvants are typically used to improve the delivery of pesticides,

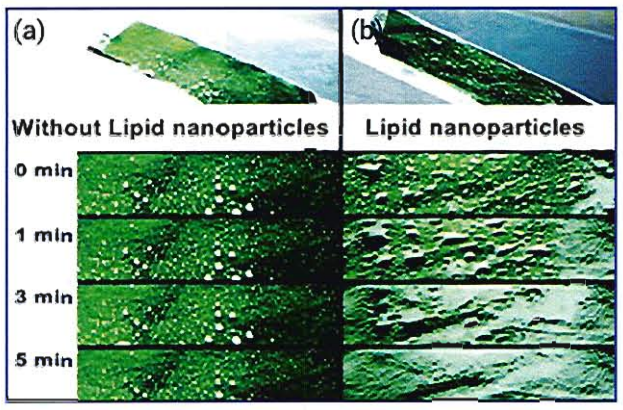

Fig. 10 Dispersion of pesticide solution (A) without lipid nanoparticles (B) with 1% lipid nanoparticles

but these have limited efficacy and several of them affect the leaves adversely. At present, oil-based adjuvants are used to reduce the surface tension of drops of spray that slows down its retraction and bouncing off.

The mixture of nanoparticles prepared from plant oils in small quantities and water form a 2 to 3 nanometres thin coat on the leaf and allows this mixture to stick to the surface of plants. This material remarkably coats the leaf surface within a few milliseconds; subsequently the droplets spread. A natural lipid compound was extracted from the sunflower oil which is edible, biocompatible and is also used as a food emulsifier. This can improve the efficiency of delivering pesticides to the targeted area on plants. In an experimental study, 10 gm of material per litre was found enough for effective pesticide spray; that may vary after the field trials.

Artificial Leaf Creates Fuel from Sunlight & Water

CSIR-NCL has developed an artificial leaf that absorbs sunlight to generate hydrogen fuel from water, promising clean energy for powering eco-friendly cars in the future. The ultra-thin wireless device mimics plant leaves to produce energy using water and sunlight. The natural leaf system is simulated by means of semiconductors stacked in a manner to mimic plant leaves to produce energy using water and sunlight. Production of hydrogen from natural resources such as sunlight and water

could be the ultimate solution to our energy and environment problems. At present, hydrogen is produced from fossil fuels by steam reforming that emits a large amount of carbon dioxide. Sunlight could be exploited through the year to produce energy or hydrogen. When visible light strikes the semiconductors in the device, electrons move in one direction, producing electric current. The current almost instantaneously splits water into hydrogen, which is believed to be one of the cleanest forms of fuel as its main by-product is water. The device of an area of 23 square centimetres could produce 6 litres of hydrogen fuel per hour. The device has been patented and efforts are being made to look out for industrial partners to move ahead.

Electrosynthesis of Nitrogen-Doped Blue Luminescent Phosphorene Quantum Dots (NPQDs)

Quantum Dots have received significant research interests owing to their unique properties applicable to various promising application including Nano-electronic devices. CSIR-CECRI reported a facile one-step route for the electrosynthesis of Nitrogen-Doped Blue Luminescent Phosphorene Quantum Dots (NPQDs) from Black Phosphorous (BP) at room temperature. This is the first report on the electrosynthesis of NPQDs. The researchers further demonstrated that the nitrogen percentage in NPQDs can be varied by the appropriate choice of solvent and supporting electrolyte. NPQDs synthesised in this work have an average size of 6 ± 1.5nm (N=50) and exhibit ca. 88.7% quantum efficiency.

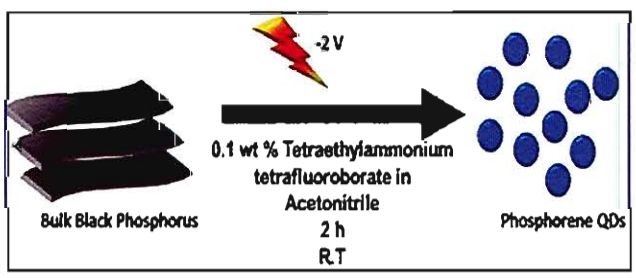

Fig. 11 Typical illustration of the electrochemical synthesis of nitrogen-containing PQDs (NPQDs-1) from Black Phosphorous

Development of Dyes to Increase Efficiency of Solar Cells

Solar cell technologies are categorized into three generations: the first and second generations comprise photovoltaic cells and utilise inorganic semiconducting materials such as single crystal silicon (Gen I) and thin film silicon and CdSe type semiconductors (Gen II); the third generation is still in the research stage which includes DSSC, and which needs a combination of cheap organic dyes and nanoparticles of titanium dioxide, to convert light into electricity.

CSIR-NCL and IIT Roorkee jointly develop porphyrin dyes with light-to-current conversion efficiencies of 7% for third generation solar cells. CSIR-NCL, Pune and IIT Roorkee have developed organic dyes that can increase the efficiency of Dye Sensitised Solar Cells (DSSC). The research has been published in the journal ACS Applied Energy Materials. Porphyrin is the building block of chlorophyll and also a complex organic molecule that allows plants to harvest light energy for photosynthesis. The first study on the use of porphyrins for power conversion efficiencies was conducted in 1993 and resulted in very low percentage – only 2.6% – not enough for practical applications. After several modifications on porphyrins, the research team utilised Zinc containing porphyrins which have been found promising.

A process has been established to produce functional porphyrins without the use of platinum and palladium catalysts and have developed simple, efficient, cost-effective sensitisers which involve fewer synthetic steps resulting in five porphyrinZn(II) complexes with power conversion efficiency 5.3% to 7.1%.

Biodiesel from Tung Oil

CSIR-CMERI has come up with a promising alternative to reduce the dependency on fossil fuels by designing and developing a biodiesel plant to convert vegetable into biodiesel.

A semi-continuous type biodiesel plant has been designed, developed and tested at CSIR-CMERI. The plant with the capacity of 600 litres/

day is able to produce biodiesel from any edible and non-edible vegetable oil irrespective of its FFA (Free Fatty Acids) content. This plant was utilized for making biodiesel based on optimized parameters to produce biodiesel from Tung seed oil (*Aleuritesfordii*).The biodiesel produced (calorific value of 9500–10500 kCal/kg) can be used to run engines and diesel gensets locally. The leftover cake can be fed into the biogas plant. The biogas produced (calorific value of 5700 kCal/kg) can be used for cooking purpose or lighting purpose (directly or through generating electricity).

Tung tree usually bears fruit within 2–4 years and reaches maximum productivity at around 10–12 years of age. The productivity of Tung oil mainly varies from 300 to 450 kg/ha. The oil content of fruit is between 14–20%, in the kernel 53–60% and the in seed 30–40%. Tung oil has been used in different industrial applications such as ceramic, paint, paper and cloth production. More recently, Tung oil (Aleuritesfordii) has been regarded as a promising non-edible source of biodiesel production.

Fig. 12 Biodiesel production from Tung oil (Aleuritesfordii)

1.3 Engineering Sciences

Deflouridation of drinking water using Nano adsorbant based domestic filter

Deflouridation of drinking water using Nano adsorbant based domestic filter is very useful to the society for providing fluoride free safe drinking. The domestic filter developed by CSIR-AMPRI works onthe principle of gravitational force and no electricity is required for purification of water. The developed filter is user friendly as one can simply put fluoride water in filter and get treated water.

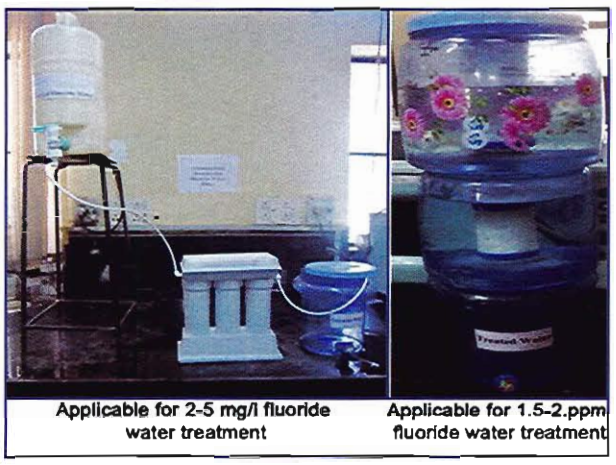

Fig. 13 (a) Fig. 13 (b)

Fig. 13 (a) Applicable for 2-5 mg/l fluoride water treatment (b) Applicable for 1.5-2 ppm fluoride water treatment

Development of Pervious Concrete

Pervious concrete is a kind of concrete with little or no fine aggregate and has a high interconnected porosity. Because of its high permeability, pervious concrete is being used widely in parking lots and pathways to allow rain/storm water runoff to permeate into the ground. CSIR-CBRI developed pervious concrete have 10-25% porosity with 10-25MPa compressive strength using locally available materials. In the first series of experiments, volume of fine aggregate has been increased up to 0.1 m^3 while two water-cement ratios were considered i.e., 0.3 and 0.32. In the second series, pervious concrete with water-cement ratio varying from 0.28 to 0.34 was cast with and without fine aggregate and super plasticizer. Fine aggregate content and super plasticizer dosage were kept constant at 50 kg/m^3 and 0.2% of cement by weight respectively. Cement content and aggregate quantity also used were 400 kg/m^3 and 1500 kg/m^3 in the first series, and 500 kg/m^3 and 1300 kg/m^3 in the second series respectively. Ordinary Portland cement has been used. A cylinder specimen of the above mixeshas been tested for abrasion resistance as per ASTM C 1747 and specimen. It is observed that mass loss decreases with increase in compressive strength.

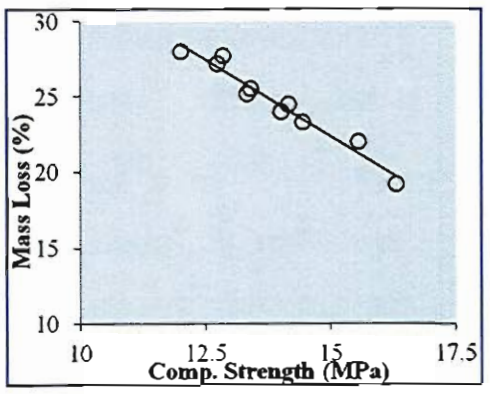

Fig. 14 (a)

Fig. 14 (b)

Fig. 14 Abrasion Resistance Test (a) Specimen after the Test (b) Mass Loss Variation with Compressive Strength in First Series of Experiments

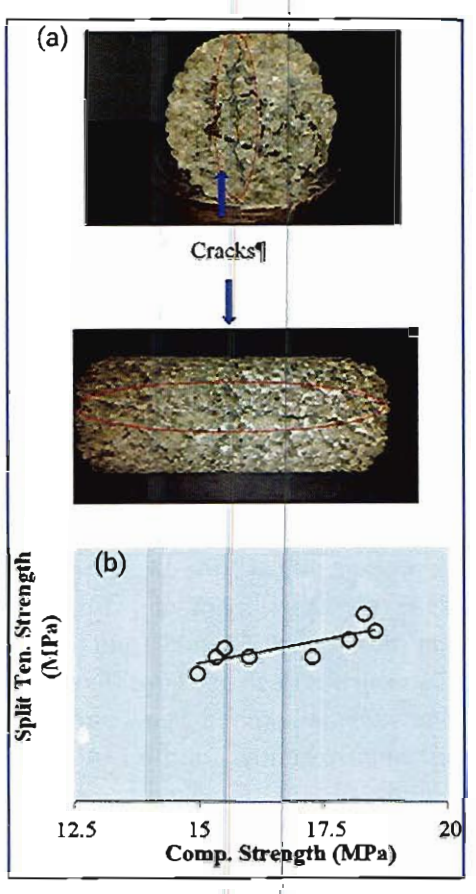

Fig. 15 Split Tensile Strength Test (a) Specimen with Cracks after the Test (b) Tensile Strength Comparison with Compressive Strength in Second Series of Experiments

In the second set of experiments, the compressive strength has been found to increase lightly with a decrease in porosity. Decrease in porosity was due to increase in cement mortar content when w/c ratio, super plasticizer and fine aggregate were increased.

Tensile strength of pervious concrete is also one of the important properties governing failure in the cases where the tensile stresses are also induced. Hence, the split tensile strength of the mixes of the second series was evaluated at 28 days as per IS 5816 because separate tensile test standards are not yet available for pervious concrete. It is seen that split tensile strength increases with increase in compressive strength and crack patterns in the specimen.

Development of a process to manufacture Sand: An Alternative to Natural River Sand

A boom in infrastructure development has led to the extensive extraction of natural river sand that physically alters rivers and coastal ecosystems. In addition, stringent guidelines of the National Green Tribunal (NGT) and Humble Supreme Court of India have forced the construction industry to choose an alternative to river sand without compromising the quality in construction. To overcome these issues, CSIR-CBRI researchers have started to explore the use of manufactured sand in construction.

Manufactured sand is a fine aggregate manufactured from other than natural sources, by processing materials, using thermal or other processes such as separation, washing, crushing and

scrubbing. It can be classified as natural Crushed Rock Sand (CRS), Recycled Fine Aggregates (RFA) and industrial by-products. These sands can be used either as full or partial replacement of natural sand in construction. It is a cost effective and eco-friendly solution.

A schematic representation of benefits of the manufactured sand over the natural sand is shown in the Figure 15.0. The natural Crushed Rock Sand (CRS) is produced by crushing rock deposits to obtain a well-graded sand, which is generally more angular and has a rougher surface texture than naturally weathered sand particles. Diorite, metamorphic siltstone, granite, limestone, sandstone, fields pathos quartzite, etc. are some of the parent rocks used for CRS production. The properties of crushed rock sand depend on their lithological character, composition and production process. Recycled fine aggregates growing waste disposal problem it will also help conserve natural sand.

CSIR-CBRI has initiated experimental investigation on natural Crushed Rock Sand (CRS) – characterize and compare the mechanical properties of the concrete with control having natural sand. It was observed that the fineness modulus of river sand was 2.31 and that of CRS was 2.60. In addition, CRS was found conforming to Zone II of IS 383:2016.Figure 16.0 shows the sieve analysis graph drawn for CRS and rivers and. Concrete of M30 grade was proportioned in accordance with the produced from the reprocessing of C&D waste can be used in concrete.

Flyash based geopolymer concrete for road construction

CSIR-CBRI and NTPC-NETRA jointly developed high strength and high-quality fly ash based geopolymer concrete for the construction of road transforming waste materials like fly ash and other materials into a valuable product as per the IRC specifications. This achievement paves the way for large-scale fly ash utilisation which is a major industrial waste produced in mammoth quantity in India. The fly ash produced by the burning of powdered coal, from NTPC, Dadri is used for the project. A geopolymer concrete road 50 m long and 3 m wide and having 40 MPa concrete strength has been successfully laid at CSIR-CBRI using this technology. It is the first of its kind in India. The road is made from fly ash, aluminate and silicate-bearing materials. As opposed to conventional cement concrete roads, this road will not need water curing. It also paves the way for bulk fly ash utilization.

Packaged fiber laser modules for industrial and medical applications

High-power fiber lasers have seen astonishingly rapid progress over the last decade in a wide range of configurations, spectral ranges, and temporal formats, and are now leading contenders for many important applications like material processing (material cutting, marking, engraving, welding etc), additive manufacturing/ 3D printing, medical surgery and defense requiring powers from a few watts to several kilowatts. CSIR-CGCRI has achieved Fiber laser characterization and prototype demonstration of 1micron commercial grade fiber laser module and field trials have been carried out for stent cutting Prototype demonstration has been made of 2micron laser and preclinical testing completed in soft tissue surgery.

Specialty Glass for HEHP Laser Systems

High power high energy (HEHP) lasers are widely used in the fields of controlled laser thermonuclear reactions, high energy density physics like equation of states experiments, plasma physics and physics of its interaction with matter. Nd3+ doped phosphate laser glass is the most preferred material as active medium

Fig. 16 Specialty Glasses

in HEHP laser systems. CSIR-CGCRI has developed of indigenous technology for the production of this specialty glass to meet the national demand.

Development of moisture sensor meter

CSIR-CGCRI has indigenously developed trace moisture sensor meter which is portable, affordable and user friendly when compared to other similar units available in the market. The moisture sensitivity ranges from 5-100 ppm and has fast response and recovery time. The developed moisture sensor meter can of utmost importance in use is transformer oil industry, food processing, gas sensing and edible oil manufacturing.

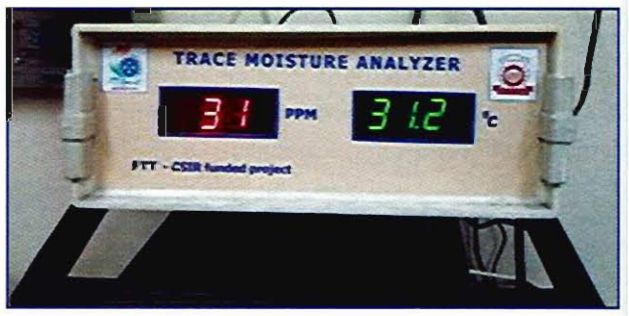

Fig. 17

Development and installation of Improved Iron Removal Plant

Iron Removal Plant developed by CSIR-CMERI has enormous social impact especially under the rural development mission of the Govt. of India. This type of initiative of CSIR-CMERI is creating an example of societal service provided by the research and development organization in India to the country. More & more peoples are benefitted by this durable, chemical free, user friendly IIRP which runs without electricity, creating for a source of income to the manufacturers and has wide opening of employment to the younger generation of rural area. Currently installed 50 numbers Iron removal plants in various districts of West Bengal is estimated to be providing iron free drinking water upto 5000 rural families. This triggered successful demonstration of water filtering and purification systems for removal of arsenic, fluoride including microbial so that safe drinking water is made available to the mass cost effectively.

Advantages:

i. Naturally available sand and gravels used for removal

ii. No electric power requirement- Implementable in remote villages

iii. Useful to community service: a small village may cover for drinking purpose only

iv. Attachable to the existing Mark-II hand pump

v. Simple in design-Operation and Maintenance

vi. Instant iron free water

vii. Cost effective

Fig. 18 Installation of Improved Iron Removal Plant

The technology has been transferred to two Indian Industries for commercialization in non-exclusive basis.

Safe Disposal of Municipal Solid Waste utilizing high temperature plasma:

The technology has been developed by CSIR-CMERI for effective & eco-friendly disposal of municipal solid waste material generated on daily basis and generation of fuel gas containing predominantly CO and H_2 utilizing high temperature (>3000°C) Plasma arc. Salient Features of the technology are:

i. Mechanized handling of waste to avoid health hazard to the associated workers

ii. Eco-friendly disposal of municipal solid waste through utilizing high temperature ionized gas / electric arc with significantly low level of toxin generation

iii. Large volume reduction, slag is 1/250th of the volume of processed solid waste

iv. Generation of fuel gas containing predominantly CO & H2

v. Unique gas cleaning system to minimize the dust accumulation in the generated fuel gas

vi. Special design consideration to prevent leakage of gas from the system during regular operation

vii. Storing facility of generated fuel gas

viii. Energy harvesting from generated gases through generation of electricity

ix. Utility of slag as construction material

Fig. 19

Model for solid waste treatment plant

The technology has been licensed to M/s Positronics Innovation Pvt. Ltd, Kolkata, WB for commercialization on non-exclusive basis.

Development of Solar Tree/Artifacts for generation of power utilizing lesser ground area

Solar Power Tree is the perfect solution to the question of availability of the land in the future for generating solar power - It take up only a fraction of land consumed by conventional systems. To bring visibility to solar technology and to enhance the beautification of a site, CSIR-CMERI has developed solar artifacts. Solar artifacts can be installed in various places to produce electricity. Moreover they add to the beautification of a place with their aesthetic design. The following are various types of solar tree:

(i) **Attapatramis** of 1kWp capacity and can provide 0.5kW electricity for 3 hours. These can be installed in the beaches, river banks, parks and even in the lawn of a bungalow.

(ii) **Solar Flora** is of 3kWp capacity and can be installed in the road side, parks and other remote areas to provide electricity.

(iii) **Surya Banaspati** is of 5kWp capacity and can be installed in the road side, parks and other remote areas to provide electricity.

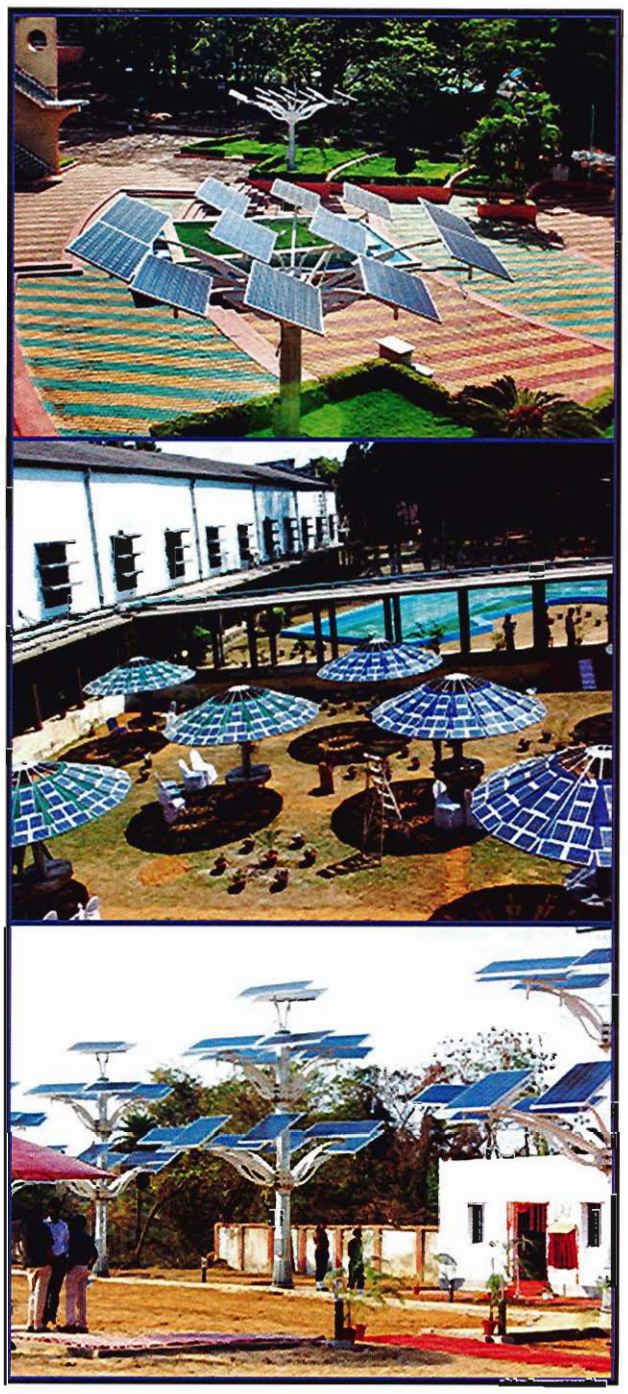

Fig. 20 Different types of solar trees

The technology has been transferred to nine Industries for commercialization in non-exclusive basis for a period of five years.

Development of fluoride removal filter

CSIR-CMERI has developed a domestic filtration unit for addressing the fluoride contamination of water. This filter is an effective solution that provides fluoride free drinking water to each and every families of the fluoride affected areas. The filter constantly keep Fluoride content in water below the permissible limit (1.5 mg/L) upto filtration of 2000L water. The filtration unit can also remove microbial contents. The features of the unit are: Flow rate: ~ 5 L / hour (approx.). Adsorbent life (average): ~2000 L. and Storage capacity: ~12 L.

Fig. 21 Components of Fluoride removal filter

Development of Intelligent and powered wheel chair

CSIR-CMERI developed wheel chair system having immense societal value for the physically challenged people, old age population for mobility and rehabilitation purpose. Intelligent & powered wheel chair design provides enhanced mobility and stability and capability to turn full 360 degrees in any narrow corridor. It can also go up slant pavements, maintaining stability. Its light weight components (main body and seating) decrease the overall weight without compromising on safety; differentially steered, six wheel configurations; longer endurance (8-10 hrs for intermittent running).

Fig. 22 Intelligent and powered wheel chair

It offers high degree of maneuverability to navigate smoothly on slopes/ramps with angle of 8-9 degrees in indoor environment; incorporation of intelligent sensor system has increased the safety of the system. The technology has been transferred to an Indian Industry for commercialization.

Large Scale Production of Graphene Oxide

Graphene oxide is extensively used in energy storage devices, polymer composites, desalination of water, conducting ink, aqueous lubrication, nano-coolant, additive for phase change materials, etc. Graphene oxide is not toxic and hazardous for the environment. The cost of commercially available graphene oxide is very high (₹ 35,000 for 0.2 g) and thus it is very difficult to use it in the aforesaid areas. CSIR-CMERI has developed technology for the production of graphene oxide starting from natural flake graphite (200 g/batch) without pre-treatment. The salient features are: production yield = 80% thickness = 1-1.8 nm; number of layers: few layer (3-4 layers); dispersible in water and most of the polar organic solvents; and oxygen content = 25-28%. The technology has been transferred to one Indian Industry for commercialization.

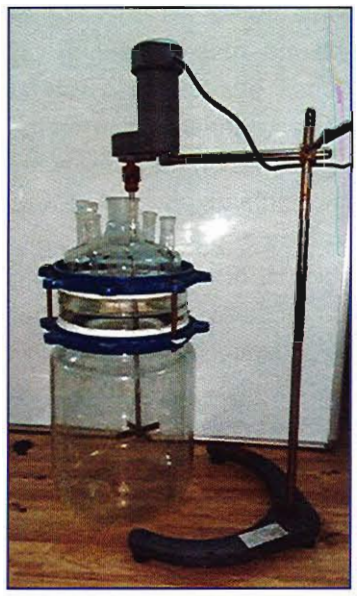

Fig. 23 Laboratory setup for Production of Graphene Oxide

Salivary Fluoride Detection Kit

CSIR-CMERI has developed an indigenous salivary fluoride level detection kitfor diagnosis of salivary fluoride level . The solution kit has been prepared by employing a chemical compound where a colour chart has been provided for the convenience of the users. One can easily operate and determine the range of fluoride level present in the body by simply tallying the colour change of the solution with the provided colour scale in the sachet. This is immensely helpful since a person by own can carry out the test without the aid of any trained personnel or experts in related domain The technology has been transferred to two Indian Industries for commercialization.

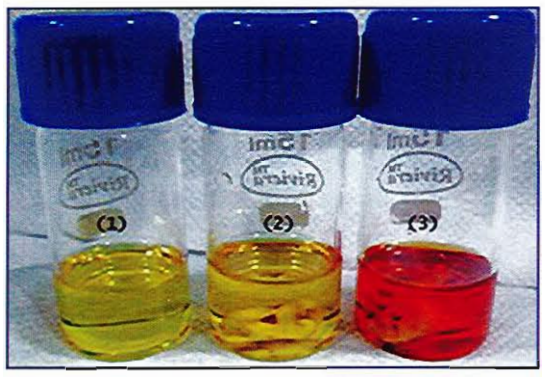

Fig. 24 (1) Sensor solution; (2) Sensor remained silent with non-fluorosis tooth sample; (3) Sensor turns red within 5 minutes of dipping the fluorosis affected tooth sample

Water Filter for Arsenic Removal

CSIR-CMERI has developed a filter for filtration of arsenic contaminated water for drinking purpose. This purification device is a commercial product that can compete with high-end water treatment products to remove arsenic contaminants from drinking water. The salient features are: domestic type adsorption based multi-stage water filtration unit; remove both arsenic (III) and arsenic (V) to the desired permissible limit (~10 ppb) of drinking water; no electricity; no running water required; Flow rate: ~ 4-5 L / hour; Adsorbent life (average): ~1800 L; and Storage capacity: ~25 L. The Technology is in high demand and the process of Transfer is under negotiation with different industries.

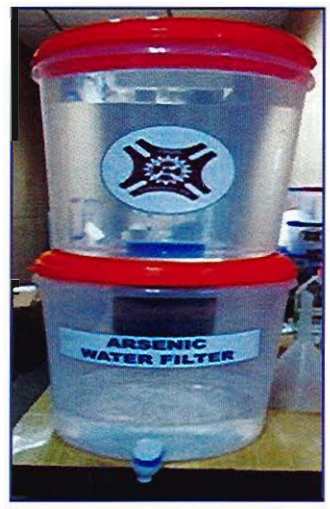

Fig. 25 Water filter for Arsenic removal

Laying of Trial Sections of Cement Grouted Bituminous Mix (CGBM) in Surat City by CSIR-CRRI

Cement grout bituminous mix is a semi flexible type of pavement comprising of open graded aggregates in the bituminous mix resulting in high air void content in the mix. The voids in the bituminous mix are filled with cement grout. Cement grouted bituminous mixes have advantages of both flexible and rigid pavements.

This hybrid mixture provides good rut resistance and a surface highly resistant to fuel and oil spillage. CSIR-CRRI laid a section of CGBM on experimental basis (two sections each 100 m length in July 2017) on roads under the Surat Municipal Corporation.

Development and Evaluation of 'Soil Nailing Technique' for stabilisation of Slope for Underpass Intersection below Road/Railway

The rapid growth in population, industries and infrastructure development in country has led to shortage of land space in the metropolitan cities and also resulted in tremendous increase in traffic volume and congestion on roads. Often, further widening of road or provision of flyovers is not feasible due to many constraints. The underpass is the only viable solution in such situations. Today, precast RCC segments are gaining popularity in underpass construction due to many advantages. The shallow underpasses can be constructed by pushing pre-cast boxes under live loading and traffic conditions. However, due to soil instability problems, often the idea of construction of underpass is dropped. CSIR-CRRI has attempted to resolve this problem by inventing a Soil Nailing Technique by which underpass construction becomes simple, easy, safe, time-saving, economical and user friendly in live loading condition. A stepwise de-stabilisation and stabilisation of Soil Nailing Technique for construction of underpass below live road/rails has been patented in India and abroad.

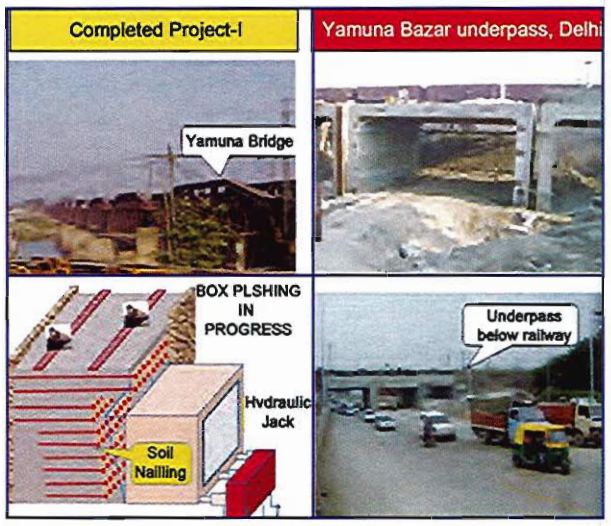

Fig. 26 Completed underpass, Yamuna Bazar, Delhi

CSIR-CRRI Designs Noise Barrier Based on Different Frequencies

At the global level, noise barriers are not designed based on the disturbing frequency generated from the transport sector. In this study, noise barriers have been designed based on three types of frequency classes for maximum reduction of noise:

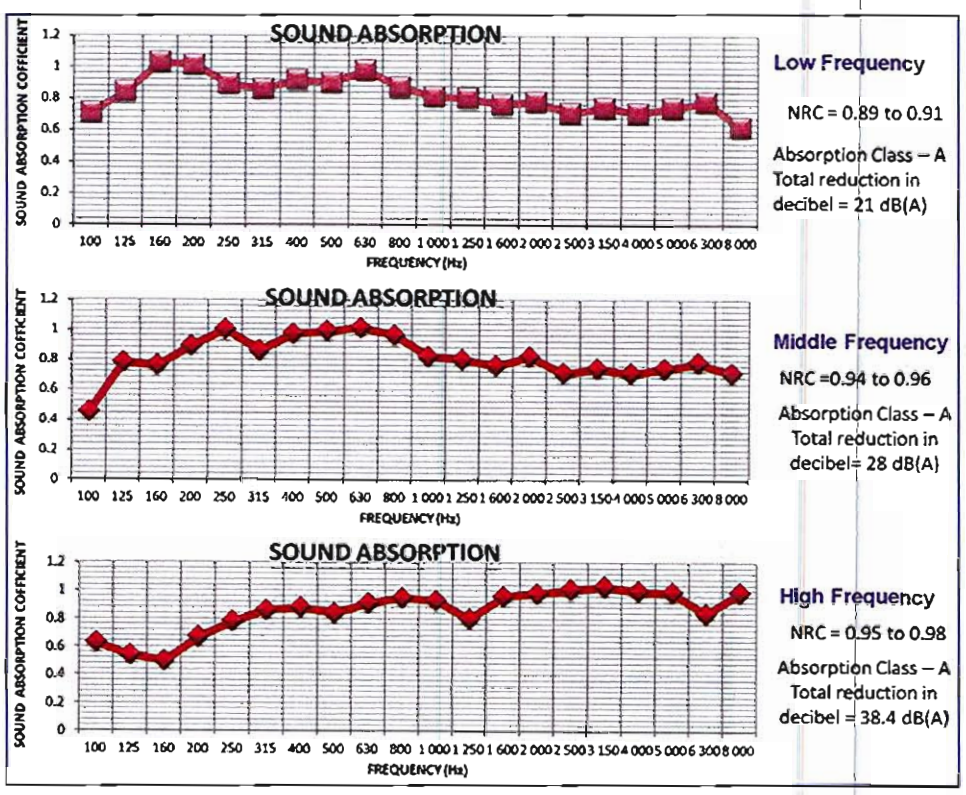

Fig. 27 Results achieved by CSIR-CRRI in different types of noise barriers

- Low frequency based Noise Barrier (<200Hz),
- Middle frequency based Noise Barrier (200-1k Hz) and
- High frequency based Noise Barrier (1k-20k Hz)

Maximizing the recovery of iron values from lean grade iron ore by reduction roasting and pelletization of high LOI and high Blaine number iron ore fines:

To maximise the iron recovery from low and lean grade iron ore resources, CSIR-IMMT has carried out extensive work by adopting reduction roasting followed by low intensity magnetic separation. In reduction roasting process, iron phase minerals i.e., goethite and hematite converts to magnetite and the swelling properties associated clay minerals is simultaneously removed. After reduction roasting, the ore is ground to its liberation size of iron phase minerals and concentrate the magnetite using low intensity magnetic separator. As the kaolinite losses its swelling properties, dewatering and filtration problems do not arise. Both tailings and concentrate can be filtered using low cost vacuum filter. The process was tested in continuous scale of 100kg/hr.

The capital cost on the beneficiation plant as compared to the conventional one will be same. The capital cost for magnetite concentrate pelletisation plant will be less. Ore having more than 40% Fe can be utilized for reduction roasting. All low grade iron ores, slimes, BHQ, BHJ and BGQ can be used to maximize the iron recovery in reduction roasting process.

Process Development for Production of Flaky Graphite, High Purity Graphite and Graphene from Natural Graphite

CSIR-IMMT has developed a process for graphite beneficiation is to maximize the flaky graphite production by introducing scrubbing technique at the beginning of the process using screw scrubber to scrub the fine ore (-10mm size). The liberated flaky graphite goes along with the other fines as overflow of screw scrubber during scrubbing. Then it is classified at 150 micron and the +150 micron contains more flaky graphite. This can be floated separately to maximise the recovery of flaky graphite. The process has been developed at pilot scale level. CSIR-IMMT has developed an improved process for preparation of graphene oxide from natural graphite by dry process using dual drive planetary ball milling process. It is a novel process for preparation of graphene oxide from high pure natural graphite using shearing action of balls in dual drive vertical swing planetary ball mill. High pure graphite produced earlier is used as the feed material for preparation of graphene. It is worth mentioning that no acids and chemicals are used to produce graphene oxide in this present process. It is a single step operation for mass production of graphene oxide from natural high pure graphite powder. Then this graphene oxide is reduced using hydrogen gas purging in the ball mill. The process yields more than 30% graphene rich high purity graphite.

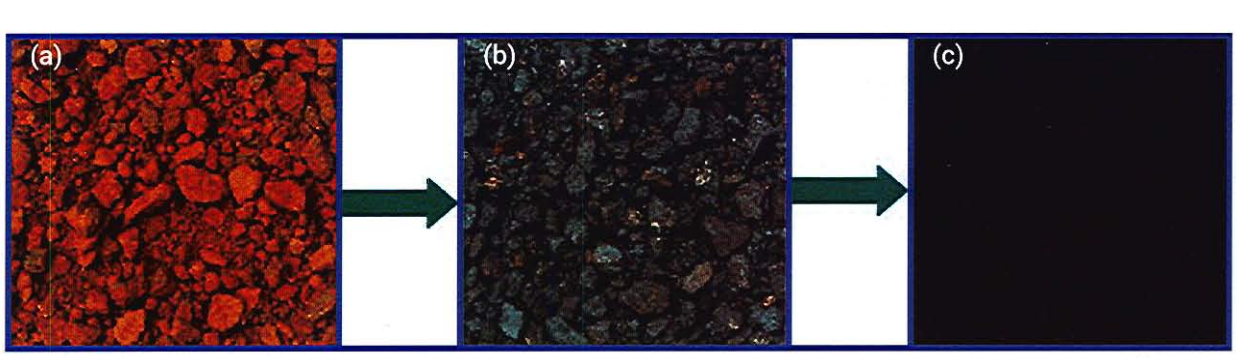

Fig. 28 (a) ROM Ore (b) Reduction Roasting Product and (c) Magnetic Product

Development of Electrophoretic coating technology for industrial application in Prevention of choking of delayed Coker tubes in Petroleum refinery and Prevention of erosion in boilers

Appropriate coating technology has been developed by CSIR-IMMT to meet the industrial needs at Reliance refinery and Pressler boiler tube manufacturers. Samples sent to Reliance refinery have met simulated operating conditions satisfactorily. Robotic coating technology is under development to coat operational tubes at the refinery site.

Electroless RGO-Ni nanocomposite coating for corrosion protection

CSIR-IMMT has developed Reducedgraphene oxide (RGO)-nickel (ni) nanocomposite coating by electroless deposition process. This nanocomposite coating can replace the existing electroless Ni coating currently used in the industry. Presently, the work is done at a laboratory scale which can be scaled up to industrial size. In electroless deposition, no electric current, no major equipment such as rectifier, no anode and cathode is required for deposition. Also deposits are less porous then electroplating, elctrophoretic deposition and hence have better corrosion resistance. Further due to the addition of RGO in the conventional Ni coating the hardness, hydrophobicity and corrosion resistance property of the coating increases. The technology has the application in Automotive parts; Aerospace component; Electronics goods; Military equipment; Printing and textile.

Electrolytic-membrane process for conversion of effluent sodium sulphate solution to sodium hydroxide and sulphuric acid

Various hydrometallurgical processes usually generate a variety of effluents or raffinate solutions containing different salts such as sodium sulphate, ammonium sulphate, sodium chloride etc. which needs an appropriate way for disposal. However, processing such raffinate solutions for the recovery of valuable chemicals will not only address the effluent disposal problems, but also may improve the overall economics of the process. Considering this industrial problem, an electrolytic-membrane process was developed by CSIR-IMMT for splitting of effluent sodium sulphate (12-15% w/w) to produce pure sodium hydroxide (25% w/w) and sulphuric acid

Fig. 29 Electroless RGO-Ni nanocomposite coated components

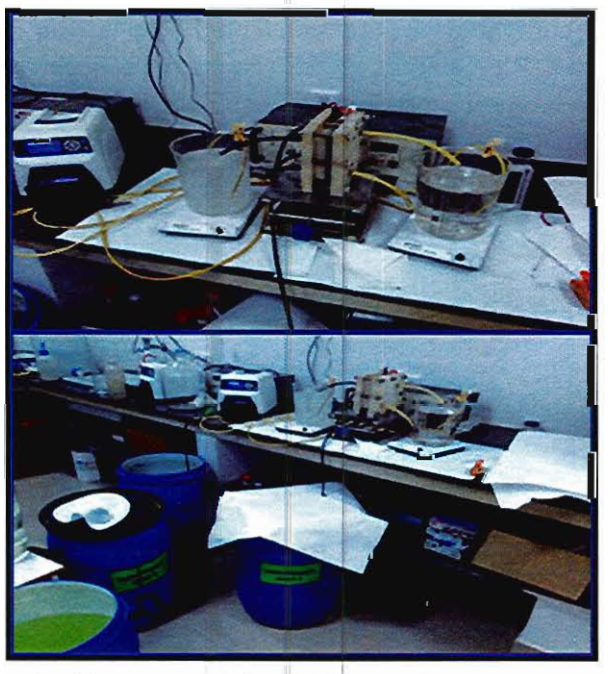

Fig. 30 Test setup for validation of electrolytic-membrane process

(5% w/w) solutions. In addition, a prototype cell was designed for Heavy Water Board (HWB), Mumbai to carry out splitting of sodium sulphate effluent for the production of sodium hydroxide and sulphuric acid. Three varieties of effluents with respect to their sodium sulphate concentrations, pH values, acid content and impurity concentrations were collected from HWB and pre-treated for the removal of solid/particulates, oil/organics and metallic impurities prior to splitting for the production of sodium hydroxide and sulphuric acid. A process flow sheet has been developed for the pre-treatment of the effluents to make them suitable for electrolytic-membrane splitting operation. Demonstration runs for 145 h and 48 h were carried out to test the splitting process. Performance of the electrolytic-membrane process has also been validated.

Advanced entrained flow gasification system

A 30 kg/hr capacity entrained flow gasification system has been developed by CSIR-IMMT to extract useful heat from agro & industrial wastes. The gasification system was designed by conceptualizing the reverse cyclone principle to maximize ash separation from the particle laden product gas. Experimental studies were carried out by blending coal with dolochar (Size: < 150 µm) wastes in different weight ratios as feedstock material for gasification process. The technology has been successfully demonstrated to NMDC Ltd., Hyderabad and Ministry of Steel, New Delhi.

Technology Demonstration of hybrid dryers for minor forest produce

In order to enhance the socio-economic condition of tribal people, field demonstration & training program on biomass & solar cum biomass dryers were carried out by CSIR-IMMT in four tribal dominated states of the country for efficient drying of minor forest products such as Mahua, Harida, Bahada, Amla, Sal seeds etc. These dryers were installed at Tamia & Mawai village of Madhya Pradesh, Amadubi & Dumariya village of Jharkhand, Kutra village of Odisha and Pargaon village of Maharashtra.

Fig. 31 Installation of hybrid dryers

Design & installation of a vertical slurry transport facility

Pipeline transport of coarse particles in form of heterogeneous mixtures is of potential importance in dredging and mining industries. In order to optimize the transport parameters and energy requirements to

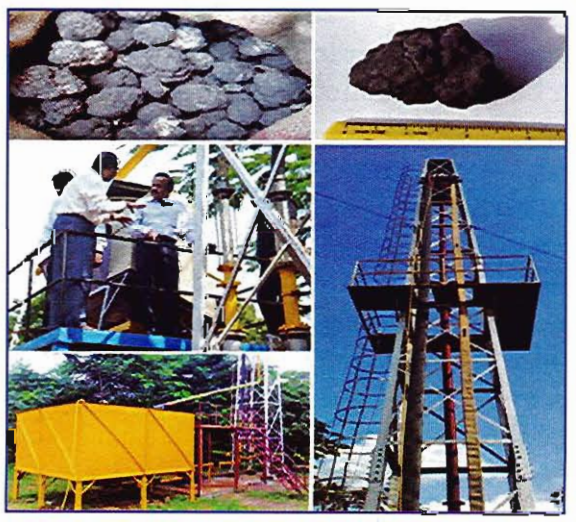

Fig. 32 Installation of a vertical slurry transport facility

improve quality, safety, economic and reliability of the vertical lifting of minerals/ores slurry, a vertical slurry transport facility was designed and installed by CSIR-IMMT. The pipe flow parameters and basic design for lifting manganese nodules slurry from a sea depth of 6.5 km were provided to National Institute of Ocean Technology, Chennai.

Processing of Tungsten Alloy (TA) Cubes

CSIR-IMMT has developed a process for manufacturing of Tungsten alloy cubes in 10kg scale for DRDL, Hyderabad for their R&D requirement in armour piercing penetrator in missile programme. Processing stages involved in making of TA Cubes with desired sintered density and mechanical properties include (i) Elemental powder characterization, (ii) Blending, (iii) Granulation, (iv) Powder compaction, (v) De-binding and (vi) Sintering. It is worth noting that each of the above processes require thorough optimization of all the parameters in order to develop the TA Cubes.

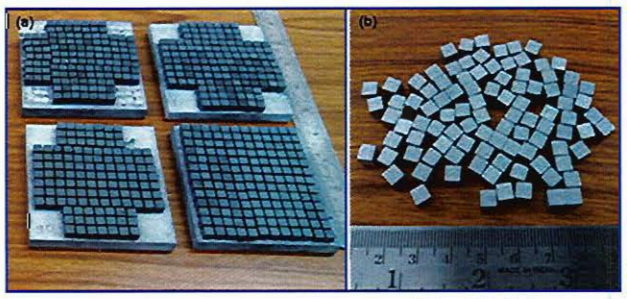

Fig. 33 (a) Fig. 33 (b)

Fig. 33 Photographs of Tungsten alloy (TA) cubes (a) green and (b) sintered

Potassium(K) enriched Biocharfertiliser from banana peduncle waste

CSIR-IMMT has developed a unique technique for utilization of potassium (k) rich abundantly available plantation waste biomass for faster production of potash enriched biochar. The specific available potassium content in potash enriched biochar was 26 %. With reference to raw biomass, specific available potassium content was enriched by 4.3 times in biochar. Due to the conversion of bulky biomass to highly concentrated potassium enriched biochar, it will be utilized easily by farmers and it can substitute the K-fertiliser use in potassium deficit soil and high potassium requiring crops and plants like wheat, corn, cotton, potato, alfalfa, sugarcane, tea, and banana etc.

Development of Ceramic Substrates for Electronics, Oxygen Sensor and Solid Oxide Fuel Cell Applications

Ceramic substrates are used for a wide range of applications in electronics, including thin and thick film microelectronics, high power and high frequency circuit RF/microwave components and capacitors or resistors. Alumina and Aluminium Nitride (AlN) are well known electro-ceramics which are being used as substrates for electronic packages, heat sinks, IC packages, microwave device packages, etc. Other ceramic substrates like YttriaStabilied Cubic Zirconia (YSZ), Scandia Stabilized Zirconia (ScSZ), NiO-YSZ, glass sealant, Gadolinia Doped Ceria (GDC), etc. find applications in Solid Oxide Fuel Cells (SOFC). There is also a great demand for thin YSZ and Al_2O_3 ceramic substrates for the fabrication of oxygen sensors.

CSIR-NAL in partnership with M/s. Carborundum Universal Ltd. (CUMI) has developed 100 and 250 µm thick Al_2O_3 and YSZ tapes. The properties of the developed Al_2O_3 and YSZ substrates are at par with the imported substrates.

CSIR- NAL has also developed expertise in the fabrication of free standing ceramic substrates with various thicknesses using both aqueous and non-aqueous based slurries. Currently, these substrates are being used for the fabrication of amperometric oxygen sensor in collaboration with Defence Bio-Engineering and Electro Medical Laboratory (DEBEL), Bangalore.

CSIR-NAL has also developed tapecasting grade powders and process for technologically important tapecast products like doped Al_2O_3, GDC, ScSZ, glass sealant, etc. Among these, ScSZ is considered as the futuristic electrolyte material for SOFC which has a large market potential.

For carrying out all these activities, acustomised tape caster was fabricated in-house. Dense AlN tapes are in high demand for space electronic packaging application and it is of paramount importance to develop this technology in the country.

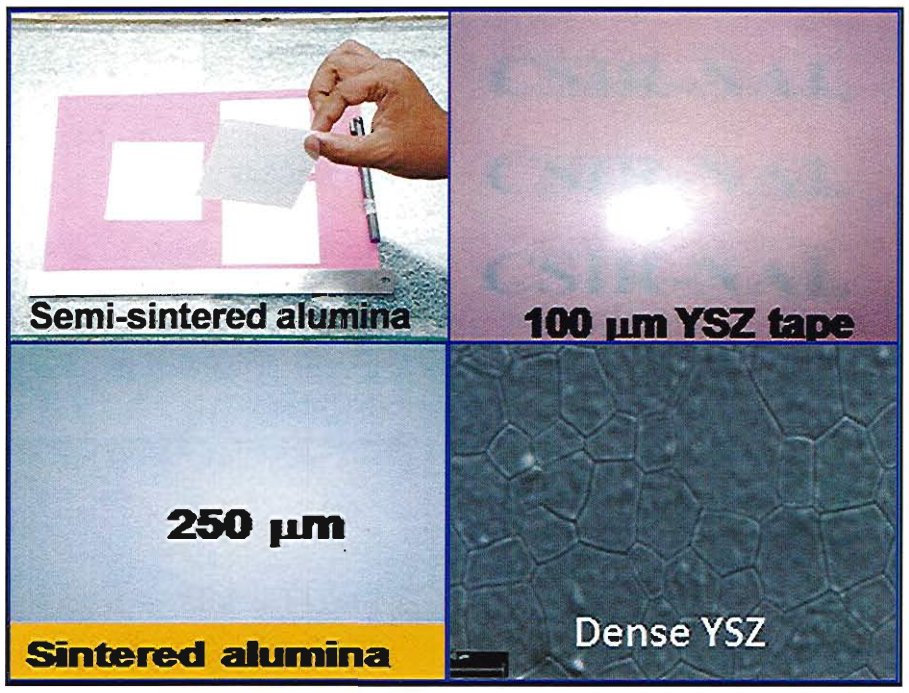

Fig: 34 Photographs showing the free standing ceramic tapes of alumina and YSZ along with the dense microstructure of YSZ

Certification of Indigenous Carbon Fiber

CSIR-NAL developed carbon fibre received certification for aerospace grade by CEMILAC in May 2017. The Ministry of Defence(MoD) would utilize the technology for establishing 100 TPA carbon fibre plant through MIDHANI. Process developments along with modifications in equipment have resulted intermediate modulus grade carbon fibers with improved tensile strength. Development of dry jet wet spinning technology has been initiated to further improve the quality of precursor fibers.

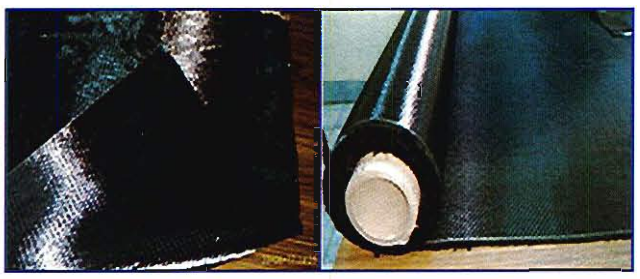

Fig: 35 Uni-directional and bi-directional fabric prepared from CSIR-NAL's carbon fiber

Development of Desktop Autoclave

The desktop autoclave was developed by CSIR-NAL to meet the expectations of academia and research institutions in establishing an affordable, low energy consuming, aerospace grade autoclave,with a working volume of 450mm diameter and 500mm length, operating conditions of 200°C temperature and 7bar pressure and an intuitive control system. The desktop autoclave was successfully commissioned and number of cure trials were carried out. Non-Exclusive

Fig: 36 Desktop Autoclave

License Agreement for production and marketing of Desktop autoclave was signed with M/s. Milvus Aero Solutions Pvt. Ltd. Bengaluru and M/s. Datasol India Pvt., Ltd.

Airboat for Cleaning Lakes

CSIR-NAL has developed an airboat using engine of Maruti 800 Car. The first-of-its-kind airboat was used to clear out weeds from Ulsoor Lake, Bangalore and has successfully undergone trials.

Fig: 37 Airboat clearing weeds at Ulsoor Lake

Tungsten recovery from low grade resources

CSIR-NML has carried out large Scale efforts at Tungsten Extraction and Recovery from lean sources, through projects funded by DRDO to the tune of Rs.~5 crores. These include "Development of Process Flowsheet for Extraction of Tungsten Metal from Hutti Tailings", and "Extraction of Tungsten Metal Powder from Recycling of Tungsten Base Heavy Alloy Scraps".

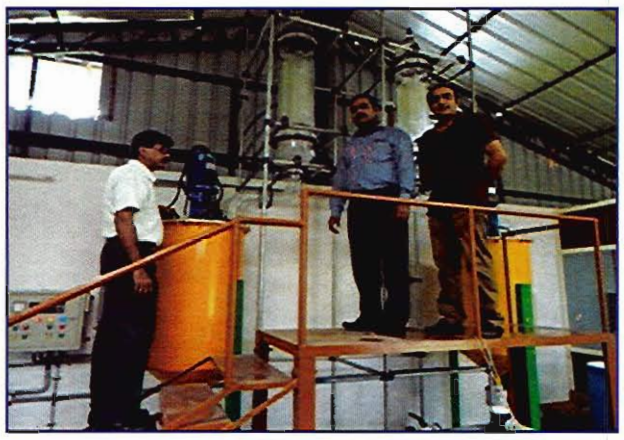

Fig: 38 Commercialization of NML tungsten extraction process

Process for extraction of Gadolinium

CSIR-NML has developed of a process for production of Gadolinium (Gd) Metal by fused salt electrolysis and the desired amount of Gd (>99% purity) was provided to IGCAR, Tamil Nadu.

Development of high hardness steels

CSIR-NML has developed a process for improving in the operational life of manganese steel blow bars of limestone primary crusher steel for development hardened steel.

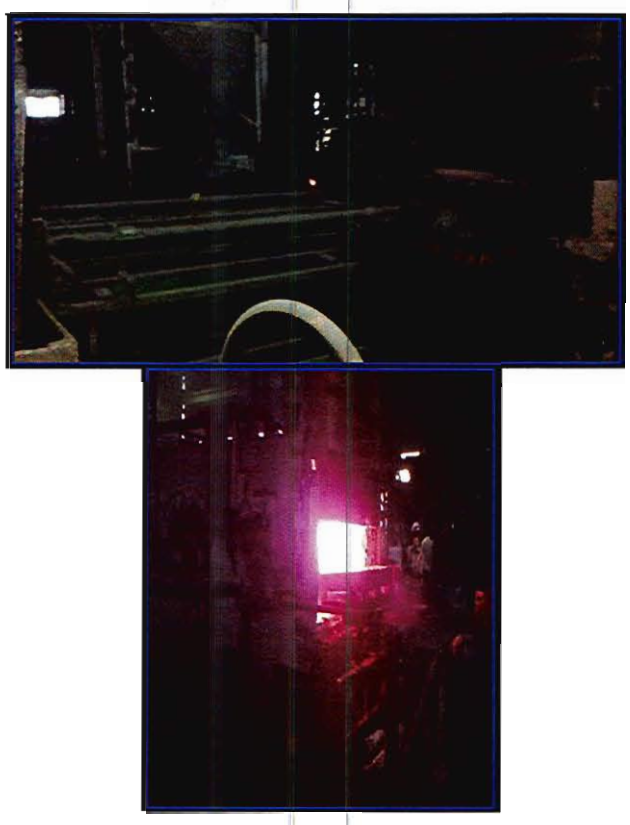

Fig: 39 Development of high hardness steels for grinding operations

Natural Composite for Stronger Bone Grafts

CSIR-NML, Jamshedpur has developed a novel nanocomposite that has shown potential to be used as a regenerative bone graft especially in regions that need high strength. The nanocomposite was synthesised through a simple and cost effective route. The composite contains carboxymethyl cellulose, gelatin and hydroxyapatite, with the hydroxyapatite in nanoscale (25-10 nm size). Since bone grafts to

be used in load-bearing applications must match the strength of the natural bone, strength and elasticity of the nanocomposite was evaluated and found it to be in the same range as human cancellous and cortical bone. Since all bone grafts need to be steam sterilised before use, the substance should be able to withstand at least 120° C. The new polymer nanocomposite is thermally stable up to 200° C. It is biodegradable and also accelerates the formation of new bone apatite under simulated body fluid. Human bone cell line (MG-63) cells were also found to be biocompatible and proliferated in the presence of the nanocomposite. In fact, the nanocomposite accelerated the bone cell line for new bone tissue formation. The compressive strength and modulus of the nanocomposite developed is in the range of human bone. So, there is no risk of damage to adjacent bones after implantation. The nanocomposite gets absorbed inside the body and new bone is formed in that place. Unlike metallic implants, there is no need to take out the new implants.

Technology for Manufacturing Textile Reinforced Concrete Panels

CSIR-SERC has developed Textile Reinforced Concrete Panels which have been used to built cost effective, durable, ecologically safe toilet units and provide sustainable sanitation. The concrete segmental panels are light in weight and can easily be handled by two persons. The roof slab is designed as two parts for easy lifting which provides confinement to the wall panels by preventing lateral movement. The construction of septic tank for the toilet is also with the same precast thin concrete segmental panels. Assembling/erection of the panels for the construction of toilet can be completed in 3 hours without any special equipment, like cranes. Construction Industry can make use of this technology for mass production of toilet core panels. This technology has been transferred to M/s. Smart Built Prefab Pvt Ltd., Hyderabad.

Fig. 40 Textile Reinforced Concrete Panels

Solution to agricultural residues (Parali) Burning

In Delhi along with the National Capital Region (NCR) especially during the winter seasons, the air and smog pollution level reaches almost 30 times more than the World Health Organization's (WHO) safe limits. The major cause of this air and smog pollution is due to the burning of agricultural residues such as paddy/wheat straw and other agro-residues in the neighboring states. It is apparent that improper management and burning of agro-residues has created severe air and smog pollution in Delhi. There is, therefore, an urgent need for finding a solution to address this serious problem with techno-economic and socially acceptable prompt solutions.

To provide a solution to reduce Delhi's smog pollution and stop burning of agro-waste parali in Delhi and neighbouring States (Haryana, Punjab and Uttar Pradesh) and converting them into useful materials, attempts have been made at the CSIR-AMPRI, Bhopal. The primary objective is to develop a technology for utilising paddy and wheat straw as raw materials for "manufacturing hybrid greenwood", which may be used as a substitute of wood or particle board. The proposed research addresses multiple issues with very well focused objectives like avoiding deforestation, utilising agro-wastes, developing termite free products, etc. for multifunctional applications in different sectors viz. housing interiors, civil infrastructure, etc.

A team of scientists of CSIR-AMPRI, Bhopal, visited the village SunheriKhalsa, ThanserTaluk of Kurukshetra District in Haryana State and explored the possibility for recycling and utilising the paddy straw in manufacturing useful materials similar to that of particle board. During their visit, the paddy straw from Haryana was collected and quick preliminary feasibility experiments for converting paddy crop residues into value-added products at CSIR-AMPRI, Bhopal, were conducted.

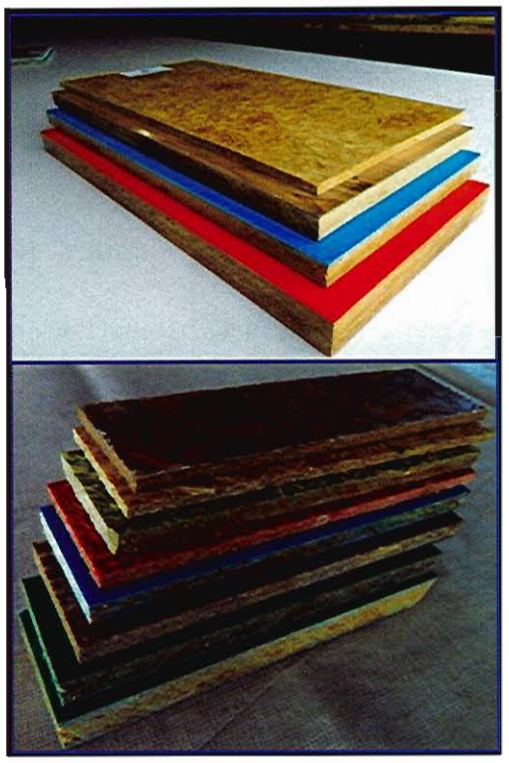

Fig. 41 Composite materials developed from paddy and wheat straw by CSIR-AMPRI Bhopal Converting Paddy Biomass into Green 'Biocoal'

Converting Paddy Biomass into Green 'Biocoal'

CSIR-NPL devised a solution to deal with the problem of stubble burning. The scientists have called for conversion of paddy biomass into green 'biocoal' to be used in thermal power plants.

According to a study published in *Current Science*, this conversion of paddy stubble into green product biocoal through torrefaction process would also help farmers to earn money using the agriculture residue. Besides, by optimizing the processing parameters of torrefaction process, desired calorific value of torrefied product has been archived, as per the study conducted in Haryana. It also pointed out that 10 per cent use of torrefied product with coal can consume 140 million tonnes of rice straw, thus considerably reducing the consumption of fossil fuels and also cutting down environmental pollution and greenhouse gas (GHG) emission. Similarly, residue of other crops like wheat, sugarcane, oilseed, maize and cotton which is estimated to be around 500 million tonnes in the country, can be used as biocoal in thermal plants after torrefaction.

1.4 Information Sciences

As part of its Climate Change Informatics (CCI) programme, CSIR-NISCAIR has developed curriculum for skill development for islanders in Lakshadweep. Also a report and programme has been developed for archiving the inherited traditional navigation manual 'Rahmani' of Lakshadweep Islands, Arabian Sea. The report has been accepted to be published as a book chapter from UK.

An analogue dynamical model for forecasting fog-induced visibility : validation over Delhi Meteorological Applications

Accurate forecasts of fog and visibility are important for many applications; while prolonged fog can adversely affect many crops, even a short duration of dense fog can lead to disruption of air and highway traffic. A forecast model of the occurrence of fog, measured in terms of visibility, is developed by CSIR-NISTADS. The model is formulated as an analogue model; thus the merit of the model is primarily based on its validation against observation. Two forecasts using two sets of meteorological fields are considered: one as the benchmark forecasts with visibility calculated from observed meteorological fields and the other based on meteorological forecasts from an atmospheric mesoscale model (Weather Research and Forecasting). While the benchmark (perfect) forecasts from observed meteorological fields provide the potential skill of the model, the mesoscale forecasts provide an assessment of realizable skill in an operational setting. The validation was carried out against hourly visibility data recorded at Indira Gandhi International Airport, Delhi during the winter months (December and January) for the period 2009–2012. Error statistics show that the analogue fog model can capture a significant part of the observed variability of fog. The forecasts have more success in forecasting intense (visibility < 500 m) and persistent (duration > 4 h) fog events. The model provides a useful forecasting tool, as shown by measures such as average error, number of false warnings and the number of misses.

1.5 Physical Sciences

LTCC/Thick-film Hotplate-based Warming of Micro-farming Unit

Micro-farming is a technique to grow tiny plants. Such plants are essential in providing the required nutrients and water content to the soldiers of the Indian Army posted in the extremely low-temperature and high-altitude regions. The germination and growth of the plants do not take place in the extreme cold climatic conditions. To solve this problem and grow the plants on a regular basis, hotplates play an important role in maintaining the required temperature inside the micro-farming unit. The thick-film hot-plates operate at 12 V DC (using portable power supplies) and get heated up in a temperature range of 80-100°C (consume low-power) and help in heating the entire micro-farming unit developed by CSIR-CEERI. The required temperature inside the micro-farming unit would be maintained at about 15-20°C for germination and growth of the seeds. The integration of hotplates inside micro-farming unit makes it portable and easily transportable to the high altitude regions for the cultivation of various crops in a single unit The hotplate integrated micro farming unit has been successfully demonstrated at DRDO-DIHAR, Leh, Ladakh and seeds of crops viz. Fenugreek, Radish, Moong and Cabbage were germinated.

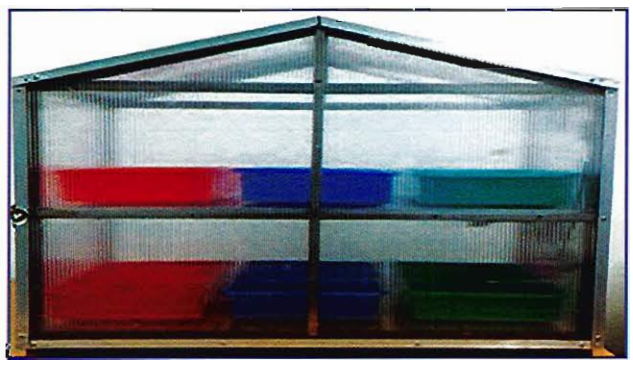

Fig. 42 Microfarming unit

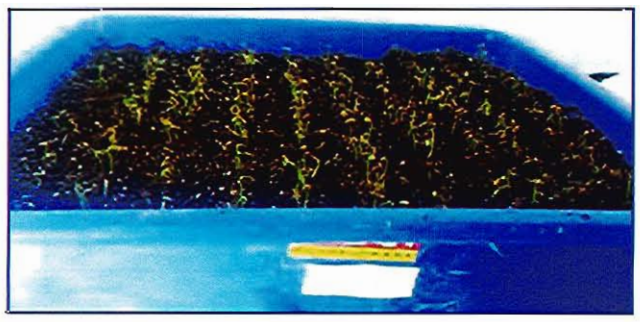

Fig. 43 Germinated seeds at DRDO-DIHAR, Leh

LTCC/Thick-film Hotplate Integrated Warm-Insoles for Shoes:

A special type of hotplate with unique interconnection technology has been designed and developed by CSIR-CEERI using Low Temperature Co-Fired Ceramic(LTCC)/thick-film technology for the purpose. The hotplates are highly rugged, reliable and provide mechanically and thermally strong interconnections. They can be battery operated with a charging time of 3-4 hours and battery runtime of 6-7 hours. The fabrication process is environmentally friendly. The insoles integrated with LTCC/thick-film hotplates are capable of keeping the feet warm near to body temperature (insole temperature around 37°C). These warm-insoles are useful for people living in extreme cold climatic regions, high-altitude cold deserts and army soldiers serving at high-altitude posts. These warm in soles are reliable and have a long battery life.

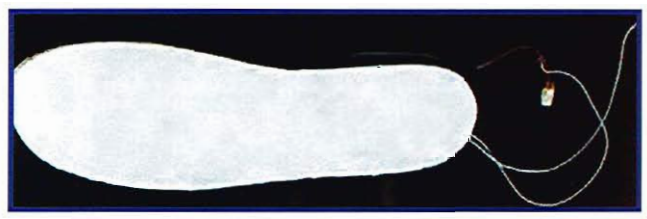

Fig. 44 LTCC/ thick-film hotplate integrated warm-insole

Instant Water-warming Unit using LTCC/ Thick-film Hotplates:

A hotplate-based instant water-warming unit has been developed by CSIR-CEERI that warms the running-water flowing through a pipe with less waiting time (~1 min.) and with low-power consumption as compared to the conventional water heating systems. The water at the outlet is heated 15-20°C more than the inlet water and flows with a flow-rate of about 250 ml/min. The instant water-warming unit does not require a storage tank and thus it requires less installation space. The product will be used in domestic applications such as kitchen, washroom, etc.

Mercury free plasma based ultraviolet light source for water treatment

CSIR-CEERI has developed a Mercury Free Plasma-UV (MFP-UV) Lamp for water purifier system which can be used in household water purifier systems, storage/ sewage/waste water treatment plants, municipality water treatment plants. The mercury-free plasma UV lamp with a novel structural design and an optimized gas mixture that produces strong spectral bands peaking at wavelengths 253 nm and 172 nm along with a weak band peaking at wavelength 265 nm, which are useful for water sterilization. Filament less light source, no end sleeves, negligible start-up tim, scalable in dimesnion, easily repaiale, boadwaelength coverage due dimer (or molecular) radiations, medium pressure lamp and mercury free. The technology has been transferred to M/s YOUWE (UV) Purifier, Jaipur, M/s ARKEN Techno Pvt. Ltd., Pune

Fig. 45 Plasma based ultraviolet light water treatment system

Solar PVT Co-Generation System

CSIR-CEERI has developed Solar PVT Co-Generation System for Potential applications Electrical Power Electricity for domestic and commercial applications. Its advantages are: Low Temperature (40°C-80°C) heat, Direct hot water, Preheating Pressurisation, Bleaching, Washing, Pasteurisation and Desalination. The Engineered Solar Photovoltaic and Thermal Co-generation System could be used forsimultaneous generation of electrical and thermal energy in a single system. The system has a Combined efficiency: 30-40%; >20% cost savings; >50% roof top savings and Pack back time: 3-4 years.

IoT Ready Smart Solar Tree

CSIR-CEERI has developed IoT enabled Smart Solar Tree for Smart cities, Decenralised Power Generation, Agricultural land, border security and gram panchayats. The 1kW and 3 kW solar tree designs optimized for a particular geographical location; Integrated lighting and cell phone charging; IoT enabled sensors for electrical performance monitoring; IoT enabled sensors for distributed sensing of environmental parameters (Temp, humidity, CO_2, PM 2.5, PM 10 etc.; Integrated smart cameras for surveillance; IoT enabled solar tree has applications ranging from decentralized power generation applciations, agricuture lands security borders, smart cities and ev charging stations. The technology has been transferred to M/s Star Rising Energy Pvt. Ltd., Ngar, Jaipur.

Amonia Gas Sensing System

CSIR-CEERI has developed Amonia Gas Sensing System which is useful correct estimation of air quality.The system has metal oxide based gas sensing platform for Ammonia (NH_3), Carbon Monoxide (H2S), Nitrogen dioxide (NO_2), Ethanol (C_2H_5OH), and Propanol (C_3H_7OH) and demonstrated developed gas sensors. The technology has been transferred to M/s MacwinIndia, New Delhi.

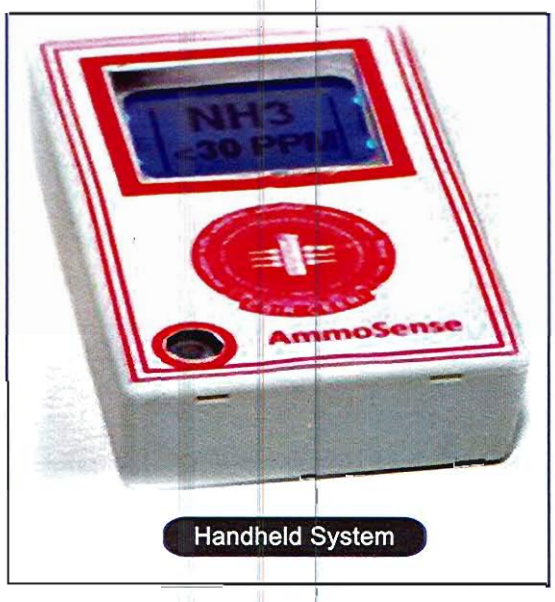

Fig. 46 Handheld Amonia Gas Sensing System

Rapid Milk Analyser

The most common adulterants found in milk are water, glucose, skimmed milk powder, urea, detergent, refined oil, caustic soda and white paint which, according to studies, are "very hazardous" to human life and can cause serious diseases like cancer. CSIR-CEERI has developed a rapid milk analyserto detect such adulterants. The adoption and deployment of the innovation in villages and milk societies would be a step forward in increasing the standards and quality of the milk. The innovation represents the first fully Indian 'concept to implementation' effort in the milk related instrumentation sector. The technology has been transferred to M/s Rajasthan Electronics & Instruments Ltd., Jaipur (Rajasthan)

Fig. 47 Rapid Milk Analyser

Handheld Milk Adulteration Tester

CSIR-CEERI has developed Handheld Milk Adulteration Tester System. The system is capable of detecting adulterants such as urea, salt, detergents, boric acid, caustic soda, Lye (NaOH), soda, hydrogen peroxide and many more unknown adulterates in raw milk. The system has the following specifications:

- Portable and user friendly system
- Electrochemical detection
- Low cost system and Green technology
- Measurement time: 40-45 Sec.
- Minimum Detection level:Urea:1gm/l; Salt: 2gm/l; detergent: 2gm/l; soda: 1gm/l; boric acid and hydrogen peroxide in ppm.
- Indigenous technology
- The Technology has been transferred to M/s Rajasthan Electronics & Instruments Ltd., Jaipur (Rajasthan)

Precision Iodine Value Analyzer

CSIR-CSIO has developed Precision Iodine Value Analyzer, which measures the degree of unsaturation (iodine value) in vegetable oils. It has applications in a host of industries such as oil extraction units, quality control and assurance laboratories, food regulatory authorities, soaps and cosmetics, bakeries, meat industry, paint industry, biodiesel analysis and charcoal industry. It is also useful in determining adulteration in edible oils and fats. Conventionally, iodine value is determined using manual titration but this method takes longer analysis time, is costly and uses toxic chemicals. The technology has been transferred to startup M/s Comfax Systems Chandigarh.

Postural Stability System

CSIR-CSIO has developed a postural stability system which accesses the standing balance of a person. Postural stability is achieved by maintaining an upright body alignment against gravitational force and preserving the equilibrium of the centre of mass (CoM) in an individual's base of support. Successful postural control requires the contribution from a complex sensory system comprising visual, somatosensory, and vestibular modalities as well as motor control systems. Assessment of standing balance is essential to the treatment of instability in the neurologic patient.

System assesses pressure fluctuations produced by the heels and toes of the subject standing on a platforms having force sensors placed at the specific locations for each foot. Calculated parameters help in assessing interactions of the neurophysiological and neuro-anatomic subsystems involved in balance control. Ground reaction forces is amongst the prominent parameters used for Gait assessment. It gives an approximation of the projection of body's centre of mass on the ground. The developed system measures centre of foot pressure estimation, gait events like balance stability and lateral fall are also detected.

Portable Harness Ambulatory System

Portable Harness Ambulatory System developed by CSIR-CSIO is a gait supporting aid for patients undergoing gait rehabilitation. It helps in eliminating/ minimizing fall and fear of fall in patients during rehabilitation therapy. It is used in physical therapy and exercise training for people with neurological or musculoskeletal injuries or muscle weakness. It supports patient by using a body harness and patient is lifted partially against gravity. The amount of support provided is dependent on the musculoskeletal strength and stability of the patient. Suspension systems function by offsetting a percentage of body mass while providing balance Support. Gait rehabilitation therapy/training using Portable Harness Ambulatory System (PHAS) are more effective and efficient. The salient features of the system are:

- Controllable and modular design which adjusts geometry according to patient needs
- Compatible with support for lifting patient from seated position such as a wheelchair
- Includes adjustable parallel arm supports / hand rails and control boards acessible from either side of machine.
- Supports patients weighing from 60kgs to 180kgs.
- Includes support for vest size 65-140 cms (adults) and 40-90 cms (children)

Gas clouds/Chimneys from Seismic Data using Artificial Neural Network Developed

CSIR-NGRI has developed a workflow based on neural network for the computation of new attribute(s) from a set of other seismic attributes that can discriminate geologic features from gas clouds or chimneys. Application to time migrated 3D seismic data in the Maari field of highly structured and deformed Taranaki basin of New Zealand has brought out clear gas clouds that have originated from the Late Cretaceous source rocks (Pakawau Group) and migrated into the Eocene (Kapuni Group) and Miocene (Mahakatini Group) formations (Mentioned in the figure). The study also reveals that gas has seeped through the overlying Pliocene to recent formations, the imprints of which are observed as pockmarks on the seabed. The findings correlate reasonably with the results from Moki-1 well in the study region. This workflow can be used for interpreting plausible geological features such as faults, mud diapirs, mud volcanoes, salt bodies, slum deposits, debris flows etc. from seismic data. Several fault intersection zones (weak zones) within the reservoirs exhibit a high probability of gas chimneys. This study acts as an add-on-tool for understanding the petroleum system and provides preventive clues for mitigating hazards in the future exploitation programme. The technique can be extended in characterising reservoir properties such as the porosity, permeability, saturation, etc.

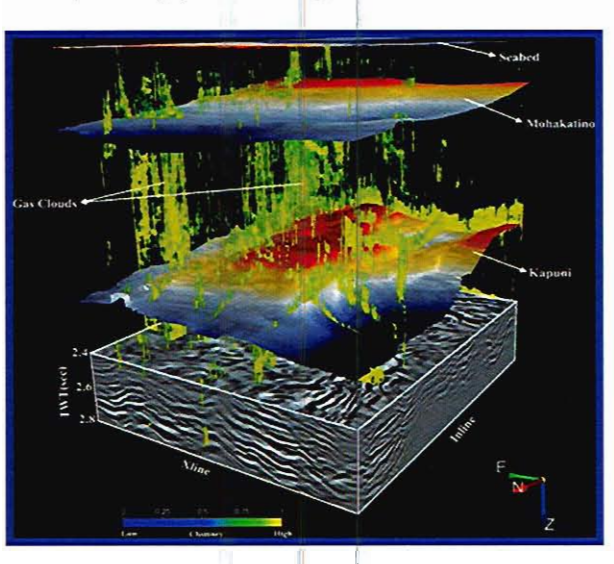

Fig. 48 3D visualisation of gas clouds rising from thermally matured source rock and propagating through Eocene and Miocene sandstone reservoirs to the seabed

Middle cretaceous geomagnetic field anomalies in the eastern Indian Ocean and their implication to the tectonic evolution of the Bay of Bengal

The occurrence of a major plate reorganisation during the Middle Cretaceous period has added to the dilemma in understanding the early evolution of the Eastern Indian Ocean. The detailed evolution of the Bay of Bengal and its conjugate Enderby Basin has remained speculative to date due to various constraints such as lack of good geophysical datasets and drill sites, and the presence of thick sedimentary load. CSIR-NIO has carried out a study to validate the occurrence of the Middle Cretaceous internal time markers in the Eastern Indian Ocean. These time markers are used to provide additional constraints

for tracing the evolution of the Eastern Indian Ocean since Late Jurassic. Identification of these markers helped confirm the timing of spreading ridge extinction in the Perth Basin as 102 Ma. The study suggests that excess crustal accretion occurred on the Indian plate since the Middle Cretaceous.

River discharge as a major driving force on spatial and temporal variations in zooplankton biomass and community structure in the Godavari estuary India

CSIR-NIO investigated variability in horizontal distribution of zooplankton biomass distribution for over 13 months in the Godavari estuary, along with physical (river discharge, temperature, salinity), chemical (nutrients, particulate organic matter), biological (phytoplankton biomass), and geological (suspended matter) properties to examine the influencing factors on their spatial and temporal variabilities. The entire estuary was filled with freshwater during peak discharge period and salinity near zero, increased to ~ 34 psu during dry period with relatively high nutrient levels during former than the latter period. Due to low flushing time (< 1 day) and high suspended load (> 500 mg L−1) during peak discharge period, picoplankton (cyanophyceae) contributed significantly to the phytoplankton biomass (Chl-a) whereas microplankton and nanoplankton (bacillariophyceae, and chlorophyceae) during moderate and mostly microplankton during dry period. Zooplankton biomass was the lowest during peak discharge period and increased during moderate followed by dry period. The zooplankton abundance was controlled by dead organic matter during peak discharge period, while both phytoplankton biomass and dead organic matter during moderate discharge and mostly phytoplankton biomass during dry period. This study suggests that significant modification of physico-chemical properties by river discharge led to changes in phytoplankton composition and dead organic matter concentrations that alters biomass, abundance, and composition of zooplankton in the Godavari estuary.

Study of Impact of dredging activities on tropical monsoonal estuary

CSIR-NIO studied impact of maintenance dredging activities on the macrobenthic community structure of a tropical monsoonal estuary (Cochin estuary), located in the southwest coast of India for three consecutive years. The results of the study indicate apparent differences in benthic fauna and sediment characteristics between dredging and non-dredging sites, while most of the hydrographical parameters (temperature, pH, DO and BOD) exhibited inconspicuous variations. The study reveals the extent of impacts associated with maintenance dredging activities in a tropical estuary, which can be used to formulate effective management strategies for the protection of ecologically and economically significant benthic communities of estuarine ecosystems.

Investigating the impacts of treated effluent discharge on coastal water health (Visakhapatnam, SW coast of Bay of Bengal, India

CSIR-NIO investigated the impacts of treated effluent discharge on physicochemical and biological properties of coastal waters from three pharmaceuticals situated along the coast of Visakhapatnam (SW Bay of Bengal). Seawater samples were collected from different sampling locations (Chippada (CHP), Tikkavanipalem (TKP) and Nakkapalli (NKP)) at 0- and 30-m depths within 2-km radius (0.5 km = inner, 1 km = middle and 2 km = outer sampling circles) from the marine outfall points. Phytoplankton cell density and total chlorophyll (TChla) concentrations were significantly correlated with dissolved inorganic nutrient concentrations. CHP (December) represented a diatom bloom condition where the highest concentrations of diatom cells, total chlorophyll (TChla), dissolved oxygen coupled with lower zooplankton abundance and low nutrient levels were noticed. The centric diatom, Chaetoceros sp. (> 50%) dominated the phytoplankton community. TKP (March) represented a post-diatom bloom phase with the dominance of Pseudo-nitzschiaseriata; zooplankton abundance and nutrient concentrations were minimum. Conversely, NKP (April) represented a warm well-stratified heterotrophic period with maximum zooplankton and minimum phytoplankton density. Dinoflagellate abundance increased at this station. Relatively higher water temperature, salinity, inorganic nutrients coupled with very low concentrations of dissolved oxygen, TChla and pH

were observed at this station. Copepods dominated the zooplankton communities in all stations and showed their highest abundance in the innermost sampling circles. Treated effluent discharge did not seem to have any significant impact at these discharge points.

Efficient bioremediation of tannery wastewater by monostrains and consortium of marineChlorella sp. and Phormidium sp.

CSIR-NIO evaluated the bioremediation potential of two marine microalgae Chlorella sp. and Phormidium sp., both individually and in consortium, to reduce various pollutants in tannery wastewater (TW). The microalgae were grown in hazardous 100% TW for 20 days, and the reductions in biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN), total phosphorous (TP), chromium (Cr) and total dissolved solids (TDS) of the wastewater monitored periodically. Both marine isolates reduced the BOD and COD by ≥90% in the consortium and by over 80% individually. Concentrations of TN and TP were reduced by 91.16% and 88%, respectively, by the consortium. Removal/biosorption efficiencies for chromium ranged from 90.17-94.45%. Notably, the TDS, the most difficult to deal with, were reduced by >50% within 20 days by the consortium. The novel consortium developed in this study reduced most of the ecologically harmful components in the TW to within the permissible limits of discharge in about 5 to 15 days of treatment. Thus, both the tested marine strains of Chlorella and Phormidium sp. are promising for bioremediating/detoxifying TW and adequately improve the water quality for safe discharge into open water bodies, in particular when used as a consortium.

Vitamin D Deficiency due to Air Pollution in Delhi

CSIR-NPL has carried a study which shows that increase in aerosol pollution is responsible for deficiency of Vitamin D in the residents of Delhi. Air pollution is majorly caused by the burning of fossil fuels, plastic waste, industrialization, agricultural waste, etc. By all these activities aerosols, which are solid and liquid particles, are spread in the atmosphere. According to the study, there is an increase in Aerosol Optical Depth (AOD), which indicates the amount of sunlight that is prevented from reaching the earth's surface by aerosol particles has decreased the ultraviolet radiation over the Delhi region. A major decrease in UVB radiation is causing Vitamin D deficiency in citizens of Delhi which may lead to bone mineralization resulting in bone softening diseases such as rickets among children. UVA reach the earth's surface to the maximum which causes many health and skin problems whereas most of the UVB radiations are absorbed by the earth's atmosphere. During the last one and a half decade, it has been observed that there is a 10% decrease in UVA and a 20% decrease in UVB. Due to the heavy pollution in the capital, the residents prefer to stay indoors and because of high temperature are forced to avoid sun exposure as much as possible which leads to the deficiency of Vitamin D. It has also been observed that for almost the last 17 years UVA and UVB are decreasing at the rate of 0.07 W/m^2 and 0.003 W/m^2 respectively every year with a 0.005 increase in AOD every year over Delhi.

High-Volume PM2.5 Impactor Sampler

CSIR-NPL has successfully developed, patented and transferred a technology, "High-Volume PM2.5 Impactor Sampler" to an industry. This technology involves a novel design of PM2.5 impactor sampler, which segregates particulate matter (PM) > 2.5 µm size (aerodynamic diameter) and facilitate to collect ≤ 2.5 µm size particles suspended in ambient air on filter size 8 inch × 10 inch with a high-flow rate (1.13 m^3/min, i.e. 40 cfm).

Indigenous Anti-Counterfeit Ink

CSIR-NPL has developed a process for making a high security ink that makes counterfeiting difficult. Security inks are essential and crucial for printing of currency. They help prevent any counterfeits, and in such an event make their detection easy. The first step followed in detection of a counterfeit is to scan it under UV light. One could then clearly see features that are normally not visible, since those features are printed with a special ink that glows or fluoresces only when exposed to ultraviolet radiations. However, many such inks already in use need a special surface that is "UV bland" to be effective. In other words, they

Fig. 49 Prints Using The New Security Ink Appear Differently Under Normal Light (A) And Under UV Light (B)

need a special paper that itselfdoes not glow under UV light. The ink developed does not need such special surfaces. It is printable on all papers and surfaces. Not only that, the ink can be tested both under UV and Infrared lights. This dual-mode glowing by the ink adds to its secure nature making it doubly counterfeit proof.The "ink is formulated from a cost-effective dual mode luminescent composite pigment. It is prepared by a combination of rare earth elements like Gadolinium, Ytterbium and Erbium oxides with phosphors such as Zinc and Manganese Sulphide. The ink designed by CSIR-NPL shines bright yellow under UV and intense red when under IR.

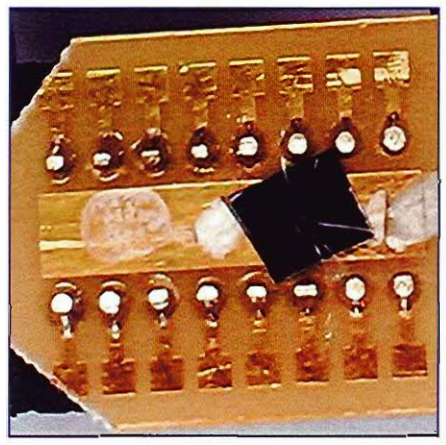

Fig. 50 Single-layer graphene grown at CSIR-NPL

CSIR-NPL Develops Device for Single-layer Graphene

CSIR-NPL has designed a low-pressure chemical vapour deposition (LPCVD) device that allows high quality, single-layer graphene measuring 4 inches in length and 2 inches in width to be grown. The quality of the single-layer graphene is metrology-grade, and can be used in next-generation quantum devices. The quality of the single-layer graphene grown using this device is also superior. CSIR-NPL published its study in *ACS Omega*. The technology is ready for transfer.

2.0 CONSULTANCY DEVELOPMENT CENTRE (CDC)

2.1 Introduction

Consultancy Development Centre (CDC) is an Autonomous Institution of the Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology, Government of India set up for promotion, development and strengthening of consultancy skills and capabilities in the country including enhancement of export of consultancy and professional services.

In the changed policy and economic environment at national and international levels, "Knowledge" is being considered as "Power" and consultancy is a knowledge based profession. CDC aims at fostering and promoting intellectual cross - fertilization of knowledge and ideas at regional and sub- regional levels within the country and interaction at the international level as well.

2.2 Activities

During the financial year 2017-18, plan support of ₹ 100.00 lakhs was received from DSIR for carrying out specific projects & activities. Besides plan support activities, CDC undertook various funded projects from various Ministries/Departments of the Government of India.

CDC regularly brings out biannual Journal – Consulting Ahead. Consulting Ahead is devoted to the publication of articles advancing knowledge through research and cases in all sectors and disciplines of consulting. The objective of Consulting Ahead is to become a source of innovative thoughts, knowledge and information of concern for consultants, clients, policy makers, academicians and professionals from various disciplines. It also aims at sharing of professional achievements, professional concerns and providing a global perspective to consulting profession.

2.3 Funded Projects

Activities (including Funded Projects) for the period 01.01.2018 to 31.03.2019 including on going activities are as follows:

- Selection of System Integrator(SI) for 'Design, Development Implementation and Support for Digital University Project for Magadh University, Bodhgaya.
- Study on "Need based interventions for better marketability of Handicraft Clusters in Uttar Pradesh (Wooden crafts in Nagina and Zari/ Zardozi crafts in Varanasi)".
- Study on "Preparation of Strategic Roadmap for Metal Handicrafts Service Centre (MHSC), Moradabad".
- Training and Consultancy Services for Implementation of ISO 9001: 2015 Quality Management System (QMS) at CSIR-IHBT Institute of Himalayan Bioresource Technology, Palampur.
- Capacity Assessment of MSE Units for National Small Industries Corporation (NSIC) as part of their Single Point Registration (SPR) Scheme.
- Training and Consultancy Services for Implementation of ISO 9001:2008 Quality Management System (QMS) at National Research Development Corporation (NRDC), Delhi.
- Consultancy Services for "Selection of Agency/SI regarding Implementation of Online Attendance Management System in various institutions of the Health Department" – Dept of Health & Family Welfare, Punjab Govt
- Consultancy services for Study on "DC-MSME schemes for MSME Sector – with focus on North Eastern Region including Sikkim"- O/o DC (MSME), Ministry of MSME, Govt. of India
- Contents Development for Certificate Programme in Strategy Consulting.

2.4 Financial Performance

During the financial year 2017-18, Expenditure of ₹ 291.22 lakhs was incurred and the total revenue generation from various programmes & activities during the year was ₹ 209.68 lakhs.